(NASA-CR-144320) EXPANSION AND IMPROVEMENT OF THE FORMA SYSTEM FOR RESPONSE AND LOAD ANALYSIS. VOLUME 2C: LISTINGS, FINITE ELEMENT FORMA SUBROUTINES (MARTIN MARIETTA CORP.) 119 P HC $5.50 CSCL 13M G3/39

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EXPANSION AND IMPROVEMENT OF THE FORMA SYSTEM FOR RESPONSE AND LOAD ANALYSIS

Volume IIC - Listings, Finite Element FORMA Subroutines

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FOREWORD

This report presents results of the expansion and improvement of the FORMA system for response and load analysis. The acronym FORMA stands for FORTRAN Matrix Analysis. The study, performed from 16 May 1975 through 17 May 1976 was conducted by the Analytical Mechanics Department, Martin Marietta Corporation, Denver Division, under the contract NAS8-31375. The program was administered by the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama under the direction of Dr. John R. Admire, Structural Dynamics Division, Systems Dynamics Laboratory.

This report is published in seven volumes:

Volume I - Programming Manual,
Volume IIA - Listings, Dense FORMA Subroutines,
Volume IIB - Listings, Sparse FORMA Subroutines,
Volume IIC - Listings, Finite Element FORMA Subroutines,
Volume IIIA - Explanations, Dense FORMA Subroutines,
Volume IIIB - Explanations, Sparse FORMA Subroutines, and
Volume IIIC - Explanations, Finite Element FORMA Subroutines.

CONTENTS

ABSTRACT

This report presents techniques for the solution of structural dynamic systems on an electronic digital computer using FORMA (FORTRAN Matrix Analysis).

FORMA is a library of subroutines coded in FORTRAN IV for the efficient solution of structural dynamics problems. These subroutines are in the form of building blocks that can be put together to solve a large variety of structural dynamics problems. The obvious advantage of the building block approach is that programming and checkout time are limited to that required for putting the blocks together in the proper order.

The FORMA method has advantageous features such as:

1. subroutines in the library have been used extensively for many years and as a result are well checked out and debugged;

2. method will work on any computer with a FORTRAN IV compiler;

3. incorporation of new subroutines is no problem;

4. basic FORTRAN statements may be used to give extreme flexibility in writing a program.

Two programming techniques are used in FORMA: dense and sparse.

ACKNOWLEDGMENTS

The editor expresses his appreciation to those individuals whose assistance was necessary for the successful completion of this report. Dr. John R. Admire was instrumental in the definition of the program scope and contributed many valuable suggestions. Messrs. Carl Bodley, Wilcomb Benfield, Darrell Devers, Richard Hruda, Roger Philippus, and Herbert Wilkening, all of the Analytical Mechanics Department, Denver Division of Martin Marietta Corporation, have contributed ideas, as well as subroutines, in the formulation of the FORMA library.

The editor also expresses his appreciation to those persons who developed FORTRAN, particularly the subroutine concept of that programming tool.

I. INTRODUCTION

A listing of the source deck of each finite element FORMA subroutine is given in this volume to remove the "black box" aura of the subroutines so that the analyst may better understand the detailed operations of each subroutine.

The FORTRAN IV programming language is used in all finite element FORMA subroutines.

II. SUBROUTINE LISTINGS

The subroutines are given in alphabetical order with numbers coming before letters.

```
      SUBROUTINE AXIAL  (XYZ,JDOF,EUL,NUTEL,NJ,
     *                   NUTMX,NUTKX,NUTLT,NUTST,
     *                   W,T,S,KX,KJ,KE,KW)
      DIMENSION XYZ(KX,1),JDOF(KJ,1),EUL(KE,1),W(KW,1),T(KW,1),S(KW,1)
      DIMENSION CJ(3,2), EJ(3,2), IV1(6)
      DATA NAMEL/6HAXIAL /, NRW,NRLT/6,2/, IBLNK/6H      /, KCJ/3/
      DATA NIT,NOT/5,6/
C
C  SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
C     MASS MATRICES AND IVECS (ON NUTMX),
C     STIFFNESS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
C     AND IVECS (ON NUTKX),
C     LOCAL LOAD TRANSFORMATION MATRICES AND IVECS (ON NUTLT),
C     STRESS TRANSFORMATION MATRICES AND IVECS (ON NUTST)
C  FOR AXIAL ROD ELEMENTS.
C  MASS, STIFFNESS MATRICES ARE IN GLOBAL COORDINATE DIRECTIONS.
C  GLOBAL COORDINATE ORDER FOR EACH ELEMENT IS
C     (U,V,W) JOINT 1, THEN JOINT 2.
C  WHERE U,V,W ARE TRANSLATIONS.
C  IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
C     IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C     IVEC(3)=0   OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINS
C                 ELEMENT DOF 3 TO ZERO MOTION.
C  GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT ROD ENDS IN GLOBAL
C  COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C  DIRECTIONS.
C  ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C     (PU,PV,PW) JOINT 1, THEN JOINT 2.
C  WHERE P IS FORCE.
C  LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT ROD ENDS IN LOCAL
C  COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
C  DIRECTIONS.
C  ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
C     PX1,PX2
C  WHERE PX IS AXIAL FORCE.
C  PX1(-), PX2(+) IS TENSION. PX1(+), PX2(-) IS COMPRESSION.
C  STRESS TRANSFORMATION MATRIX RELATES STRESS AT ROD ENDS IN LOCAL
C  COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C  ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C     SIGMA-X1, SIGMA-X2
C  WHERE SIGMA IS NORMAL STRESS.
C  SX1(-), SX2(+) IS TENSION. SX1(+), SX2(-) IS COMPRESSION.
C  DATA ARRANGEMENT ON NUTMX, NUTKX, NUTLT, NUTST FOR EACH FINITE
C  ELEMENT IS (W=M,K,LT,ST)
C     WRITE (NUTWX) NAMEW,NEL,NR,NC,NAMEL,(IBLNK,I=1,5),
C                   ((W(I,J),I=1,NR),J=1,NC),(IVEC(I),I=1,NC)
C  CALLS FORMA SUBROUTINES MASIA, PAGEHD, STFIA, ZZBOMB.
C  DEVELOPED BY WA BENFIELD, CS BODLEY, RL WOHLEN. JANUARY 1973.
C  LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C  ***********************************************************************
C  INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = 5, DATA IS
C  READ FROM CARDS.
C     NAMEM,NAMEK,NAMELT,NAMEST                       FORMAT (4(A6,4X)
C     RO,E                                            FORMAT (2(5X,E10))
```

```
C  20 NEL,J1,J2,A1,A2                              FORMAT (3I5,2E10)
C     IF (J1 .EQ. 0) RETURN
C     GO TO 20
C
C  DEFINITION OF INPUT VARIABLES.
C  NAMEM  = TYPE OF MASS MATRIX WANTED.
C         = M1, DIAGONAL LUMPED.
C         = M2, CONSISTENT.
C         = 6H        OR 6HNOMASS, NO MASS MATRIX CALCULATED.
C  NAMEK  = TYPE OF STIFFNESS MATRIX WANTED.
C         = K1, CONSTANT AXIAL FORCE ASSUMED.
C         = 6H        OR 6HNOSTIF, NO STIFFNESS MATRIX CALCULATED.
C  NAMELT = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES.
C         = 6H        OR 6HNOLOAD, NO LOAD TRANSFORMATIONS CALCULATED.
C  NAMEST = IDENTIFICATION NAME FOR STRESS TRANSFORMATION MATRICES.
C         = 6H        OR 6HNOSTRS, NO STRESS TRANSFORMATIONS CALCULATED.
C  RO     = MASS DENSITY.
C  E      = YOUNGS MODULUS OF ELASTICITY.
C  NEL    = FINITE ELEMENT NUMBER. FOR REFERENCE ONLY, NOT USED IN
C           CALCULATIONS. WRITTEN ON NUTMX, ETC.
C  J1     = JOINT NUMBER AT ROD END 1.
C  J2     = JOINT NUMBER AT ROD END 2.
C  A1     = CROSS-SECTION AREA AT ROD END 1.
C  A2     = CROSS-SECTION AREA AT ROD END 2.
C
C  EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C     I = INTEGER DATA, RIGHT ADJUSTED.
C     E = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.
C     X = CARD COLUMNS SKIPPED.
C  ************************************************************************
C
C     SUBROUTINE ARGUMENTS (ALL INPUT)
C  XYZ    = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND
C           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C           X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
C  JDOF   = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C           TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C           ROTATION DOFS. SIZE(NJ,6).
C  EUL    = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C           GLOBAL X,Y,Z PERMUTATION. SIZE(NJ,3).
C  NUTEL  = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
C           THIS SUBROUTINE. IF NUTEL = 5, DATA IS READ FROM CARDS.
C  NJ     = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C  NUTMX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C           MASS MATRICES AND IVECS ARE OUTPUT.
C           NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C           USES FORTRAN READ, WRITE.
C  NUTKX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C           STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C           MATRICES) AND IVECS ARE OUTPUT.
C           NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C           USES FORTRAN READ, WRITE.
C  NUTLT  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOCAL
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C           LOAD TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C           NUTLT MAY BE ZERO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
C           USES FORTRAN READ, WRITE.
C  NUTST  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C           STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C           NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
C           USES FORTRAN READ, WRITE.
C  W      = MATRIX WORK SPACE. MIN SIZE(6,6).
C  T      = MATRIX WORK SPACE. MIN SIZE(6,6).
C  S      = MATRIX WORK SPACE. MIN SIZE(6,6).
C  KX     = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C  KJ     = ROW DIMENSION OF JDOF IN CALLING PROGRAM.
C  KE     = ROW DIMENSION OF EUL IN CALLING PROGRAM.
C  KW     = ROW DIMENSION OF W, T, AND S IN CALLING PROGRAM. MIN=6.
C
C     NERROR  EXPLANATION
C  1 = JOINT NUMBER GREATER THAN NUMBER OF JOINTS.
C  2 = MASS MATRIX FORMED, NUTMX .LE. ZERO.
C  3 = STIFFNESS MATRIX FORMED, NUTKX .LE. ZERO.
C  4 = LT MATRIX FORMED, NUTLT .LE. ZERO.
C  5 = ST MATRIX FORMED, NUTST .LE. ZERO.
C
 1001 FORMAT (4(A6,4X))
 1002 FORMAT (2(5X,E10.0))
 1003 FORMAT (3I5,4E10.0)
 2001 FORMAT (//46X 29HINPUT DATA FOR AXIAL ELEMENTS)
 2002 FORMAT (//40X 41HINPUT DATA FOR AXIAL ELEMENTS (CONTINUED))
 2003 FORMAT (/ 16X7HMASS = A6, 9X7HSTIF = A6, 9X13HLOAD TRANS = A6,
     *           6X15HSTRESS TRANS = A6,
     *          / 18X4HRO = E10.3, 9X3HE = E10.3,
     *          //16X7HELEMENT 13X7HJOINT 1 13X7HJOINT 2 15X4HAREA
     *            16X4HAREA / 16X6HNUMBER 55X7HJOINT 1 13X7HJOINT 2 /)
 2004 FORMAT (1X 3I20, 14X E10.3, 10X E10.3)
C
C  READ AND WRITE FINITE ELEMENT DATA.
      NLINE = 0
      CALL PAGEHD
      WRITE (NOT,2001)
      READ (NUTEL,1001) NAMEM,NAMEK,NAMELT,NAMEST
      READ (NUTEL,1002) RO,E
      WRITE (NOT,2003) NAMEM,NAMEK,NAMELT,NAMEST,RO,E
   20 READ (NUTEL,1003) NEL,J1,J2,A1,A2
      IF (J1 .LE. 0) RETURN
      NLINE = NLINE + 1
      IF (NLINE .LE. 42) GO TO 30
      CALL PAGEHD
      WRITE (NOT,2002)
      WRITE (NOT,2003) NAMEM,NAMEK,NAMELT,NAMEST,RO,E
      NLINE = 0
   30 WRITE (NOT,2004) NEL,J1,J2,A1,A2
                                                              NERROR=1
      IF (J1 .GT. NJ .OR. J2 .GT. NJ ) GO TO 999
C
C  FORM FINITE ELEMENT COORDINATE LOCATIONS, EULER ANGLES, REVADD IVEC.
      DO 42 I=1,3
```

```
      CJ(I,1) = XYZ(J1,I)
      CJ(I,2) = XYZ(J2,I)
      EJ(I,1) = EUL(J1,I)
      EJ(I,2) = EUL(J2,I)
      IV1(I)   = JDOF(J1,I)
      IV1(I+3) = JDOF(J2,I)
C
C  FORM MASS MATRIX (W).
      IF (NAMEM .EQ. 6H       .OR. NAMEM .EQ. 6HNOMASS) GO TO 110
      CALL MAS1A  (CJ,EJ,A1,A2,RO,NAMEM,W,KCJ,KCJ,KW)
                                                                 NERROR=2
      IF (NUTMX .LE. 0) GO TO 999
      WRITE (NUTMX) NAMEM,NEL,NRW,NRW,NAMEL,(IBLNK,I=1,5),
     *              ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
C
C  FORM STIFFNESS MATRIX (W), LOCAL LOAD TRANSFORMATION MATRIX (T),
C  STRESS TRANSFORMATION MATRIX (S).
  110 IF (NAMEK .EQ. 6H       .OR. NAMEK .EQ. 6HNOSTIF) GO TO 20
      CALL STF1A  (CJ,EJ,A1,A2,E,NAMEK,NAMEST,W,T,S,NRST,
     *              KCJ,KCJ,KW,KW,KW)
                                                                 NERROR=3
      IF (NUTKX .LE. 0) GO TO 999
      WRITE (NUTKX) NAMEK,NEL,NRW,NRW,NAMEL,(IBLNK,I=1,5),
     *              ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
      IF (NAMELT .EQ. 6H       .OR. NAMELT .EQ. 6HNOLOAD) GO TO 115
                                                                 NERROR=4
      IF (NUTLT .LE. 0) GO TO 999
      WRITE (NUTLT) NAMELT,NEL,NRLT,NRW,NAMEL,(IBLNK,I=1,5),
     *              ((T(I,J),I=1,NRLT),J=1,NRW),(IV1(I),I=1,NRW)
  115 IF (NAMEST .EQ. 6H       .OR. NAMEST .EQ. 6HNOSTRS) GO TO 20
                                                                 NERROR=5
      IF (NUTST .LE. 0) GO TO 999
      WRITE (NUTST) NAMEST,NEL,NRST,NRW,NAMEL,(IBLNK,I=1,5),
     *              ((S(I,J),I=1,NRST),J=1,NRW),(IV1(I),I=1,NRW)
      GO TO 20
C
  999 CALL ZZBOMB (6HAXIAL ,NERROR)
      END
```

```
      SUBROUTINE B1A1   (RL,Z,KZ)
      DIMENSION Z(KZ,1)
C
C   SUBROUTINE TO CALCULATE FINITE ELEMENT...
C      BUCKLING MATRIX
C   FOR AN AXIAL ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.
C   BUCKLING MATRIX IS BASED ON UNIT AXIAL LOAD.
C   BUCKLING MATRIX IS IN LOCAL COORDINATE SYSTEM.
C   THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE IN THE X-Z PLANE
C   WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C   LOCAL COORDINATE ORDER IS
C      DZ1,DZ2
C   WHERE DZ IS TRANSLATION.
C   DEVELOPED BY  RL WOHLEN.  AUGUST 1973.
C   LAST REVISION BY RL WOHLEN.  SEPTEMBER 1973.
C
C      SUBROUTINE ARGUMENTS
C   RL = INPUT  ROD LENGTH.
C   Z  = OUTPUT BUCKLING MATRIX. SIZE(2,2).
C   KZ = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C
      C = 1./RL
      Z(1,1) = C
      Z(1,2) =-C
      Z(2,1) =-C
      Z(2,2) = C

      RETURN
      END
```

```
      SUBROUTINE B1A2   (RL,Z,KZ)
      DIMENSION Z(KZ,1)
C
C   SUBROUTINE TO CALCULATE FINITE ELEMENT...
C      BUCKLING MATRIX
C   FOR A BEAM ELEMENT WITH UNRESTRAINED BOUNDARIES.
C   BUCKLING MATRIX IS BASED ON UNIT AXIAL LOAD.
C   BUCKLING MATRIX IS IN LOCAL COORDINATE SYSTEM.
C   THE LOCAL COORDINATE SYSTEM ASSUMES THE BEAM TO LIE IN THE X-Z PLANE
C   WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C   LOCAL COORDINATE ORDER IS
C      DZ1,DZ2,TY1,TY2
C   WHERE DZ IS TRANSLATION AND TY IS ROTATION.
C   DEVELOPED BY  RL WOHLEN.  AUGUST 1973.
C   LAST REVISION BY RL WOHLEN.  SEPTEMBER 1973.
C
C      SUBROUTINE ARGUMENTS
C   RL = INPUT  ROD LENGTH.
C   Z  = OUTPUT BUCKLING MATRIX. SIZE(4,4).
C   KZ = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=4.
C
      C1 = 6./(5.*RL)
      C2 = .1
      C3 = (2.*RL)/15.
      Z(1,1) = C1
      Z(1,2) =-C1
      Z(1,3) =-C2
      Z(1,4) =-C2
      Z(2,2) = C1
      Z(2,3) = C2
      Z(2,4) = C2
      Z(3,3) = C3
      Z(3,4) =-RL/30.
      Z(4,4) = C3
      DO 10 I=1,4
      DO 10 J=I,4
   10 Z(J,I) = Z(I,J)
C
      RETURN
      END
```

```
      SUBROUTINE BAR     (XYZ,JDOF,EUL,NUTEL,NJ,
     *                    NUTMX,NUTKX,NUTBX,NUTLT,NUTST,
     *                    W,T,S,KX,KJ,KE,KW)
      DIMENSION XYZ(KX,1),JDOF(KJ,1),EUL(KE,1),W(KW,1),T(KW,1),S(KW,1)
      DIMENSION CJ(3,3), EJ(3,2), IV1(12), TR(12,12), TD(24,24)
      DIMENSION KODEK(4), KODEB(2), IFPIN(4),IV2(4)
      DATA NAMEL / 6HBAR    /
      DATA NRW,NRLT/12,12/, IBLNK/6H      /, KCJ/3/, KTR/12/,KTD/24/
      DATA NIT,NOT/5,6/
C
C  SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
C     MASS MATRICES AND IVECS (ON NUTMX),
C     STIFFNESS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
C     AND IVECS (ON NUTKX),
C     UNIT LOAD BUCKLING MATRICES AND IVECS (ON NUTBX),
C     LOCAL LOAD TRANSFORMATION MATRICES AND IVECS (ON NUTLT),
C     STRESS TRANSFORMATION MATRICES AND IVECS (ON NUTST)
C  FOR COMBINED AXIAL-TORSION-BENDING BAR ELEMENTS.
C  MASS, STIFFNESS, BUCKLING MATRICES ARE IN GLOBAL COORDINATE
C  DIRECTIONS.
C  GLOBAL COORDINATE ORDER FOR EACH ELEMENT IS
C     (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2
C  WHERE U,V,W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS.
C  IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
C     IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C     IVEC(3)=0   OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINS
C                 ELEMENT DOF 3 TO ZERO MOTION.
C  GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT BAR ENDS IN GLOBAL
C  COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C  DIRECTIONS.
C  ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C     (PU,PV,PW,MP,MQ,MR) JOINT 1, THEN JOINT 2.
C  WHERE P IS FORCE AND M IS MOMENT.
C  LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT BAR ENDS IN LOCAL
C  COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C  ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
C     PX1,PX2,MX1,MX2,PY1,PY2,MZ1,MZ2,PZ1,PZ2,MY1,MY2
C  WHERE P IS FORCE AND M IS MOMENT.
C  STRESS TRANSFORMATION MATRIX RELATES STRESS AT BAR ENDS IN LOCAL
C  COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C  ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C     PX1/A1,PX2/A2,     MX1*R1/TJ1,MX2*R2/TJ2,
C     PY1/A1,PY2/A2,MZ1*CY1/BIZ1,MZ2*CY2/BIZ2,
C     PZ1/A1,PZ2/A2,MY1*CZ1/BIY1,MY2*CZ2/BIY2
C  WHERE P IS FORCE AND M IS MOMENT.
C  DATA ARRANGEMENT ON NUTMX, NUTKX, NUTBX, NUTLT, NUTST FOR EACH
C  FINITE ELEMENT IS (W=M,K,B,LT,ST)
C     WRITE (NUTWX) NAMEW,NEL,NR,NC,NAMEL,(IBLNK,I=1,5),
C                   ((W(I,J),I=1,NR),J=1,NC),(IVEC(I),I=1,NC)
C  CALLS FORMA SUBROUTINES BUC18, MAS18, PAGEHD, STF18, ZZBOMB.
C  DEVELOPED BY WA BENFIELD, CS BODLEY, RL WOHLEN. FEBRUARY 1973.
C  LAST REVISION BY  RL WOHLEN.  APRIL 1976.
C
C  ***********************************************************************
C  INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = 5, DATA IS
```

```
C  READ FROM CARDS.
C     NAMEM,NAMEK,NAMELT,NAMEST,NAMEB,                 FORMAT (5(A6,4X),
C      (KODEK(I),I=1,4),(KODEB(I),I=1,2)               A1,A1,A2,A2,4X,A2,A2)
C     RO,E,G                                           FORMAT (3(5X,E10))
C  20 NEL,J1,J2,JREF,A1,PI1,TJ1,BIZ1,BIY1,SF,
C     IFPY1,IFPZ1,IFPY2,IFPZ2,IFTAPR                   FORMAT (4I5,5E10,E5,5A1)
C     IF (J1 .EQ. 0) RETURN
C     IF (IFTAPR .EQ. 1HT) A2,PI2,TJ2,BIZ2,BIY2   FORMAT (20X,5E10)
C  30 IF (NAMEST .EQ. 6H       .OR. NAMEST .EQ. 6HNOSTRS) GO TO 20
C     R1,CY1,CZ1,R2,CY2,CZ2                              FORMAT (20X,6E10)
C     GO TO 20
C
C  INPUT DATA REQUIREMENTS
C                         AXIAL      TORSION   BENDING        BENDING
C                         ALONG       ABOUT     ABOUT          ABOUT
C                         LOCAL X    LOCAL X   LOCAL Z        LOCAL Y
C                         -------    -------   ---------      ---------
C  MASS                   A,RO       PI,RO     A,RO           A,RO
C  STIF, LOAD TRANS       A,E        TJ,G      BIZ,A,SF,E,G   BIY,A,SF,E,G
C  BUCKLING               NONE       NONE      NONE           NONE
C  STRESS TRANS           SEE STIF   STIF+R    STIF+CY        STIF+CZ
C  FOR NO SHEAR DEFORMATION IN BENDING, SET ANY OF A(NOT IF AXIAL USED),
C  SF, OR G(NOT IF TORSION IS USED) TO ZERO. IF BENDING STRESS
C  TRANSFORMATION IS WANTED, A MUST NOT BE ZERO.
C
C  DEFINITION OF INPUT VARIABLES.
C  NAMEM  = TYPE OF MASS MATRIX WANTED.
C         = M1, DIAGONAL LUMPED.
C         = M2, CONSISTENT.
C         = 6H       OR 6HNOMASS, NO MASS MATRIX CALCULATED.
C  NAMEK  = TYPE OF STIFFNESS MATRIX WANTED.
C         = K1, CONSTANT FORCE FOR AXIAL, CONSTANT TORQUE FOR TORSION,
C               CONSTANT SHEAR AND LINEAR MOMENT FOR BENDING.
C         = 6H       OR 6HNOSTIF, NO STIFFNESS MATRIX CALCULATED.
C  NAMELT = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES.
C         = 6H       OR 6HNOLOAD, NO LOAD TRANSFORMATIONS CALCULATED.
C  NAMEST = IDENTIFICATION NAME FOR STRESS TRANSFORMATION MATRICES.
C         = 6H       OR 6HNOSTRS, NO STRESS TRANSFORMATIONS CALCULATED.
C  NAMEB  = TYPE OF BUCKLING MATRIX WANTED.
C         = B1, AXIAL ROD.
C         = B2, BEAM.
C         = 6H       OR 6HNOBUCK, NO BUCKLING MATRIX CALCULATED.
C  KODEK  = OPTION CODE FOR AXIAL, TORSION, BENDING Z, BENDING Y LOCAL
C           STIFFNESS. IF BLANK, ALL FOUR ARE CALCULATED. SIZE(4).
C           KODEK(1)=A , LOCAL STIF MATRIX IS CALCULATED FOR AXIAL
C                        (ALONG LOCAL X-AXIS).
C           KODEK(2)=T , LOCAL STIF MATRIX IS CALCULATED FOR TORSION
C                        (ABOUT LOCAL X-AXIS).
C           KODEK(3)=BZ, LOCAL STIF MATRIX IS CALCULATED FOR BENDING
C                        (ABOUT LOCAL Z-AXIS).
C           KODEK(4)=BY, LOCAL STIF MATRIX IS CALCULATED FOR BENDING
C                        (ABOUT LOCAL Y-AXIS).
C  KODEB  = OPTION CODE FOR BUCKLING IN LOCAL Y OR Z DIRECTION.
C           IF BLANK, BOTH ARE CALCULATED. SIZE(2).
C           KODEB(1)=BY, LOCAL BUCKLING MATRIX IS CALCULATED FOR
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C                         DEFLECTION IN LOCAL Y DIRECTION.
C              KODEB(2)=BZ, LOCAL BUCKLING MATRIX IS CALCULATED FOR
C                         DEFLECTION IN LOCAL Z DIRECTION.
C  RO      = MASS DENSITY.
C  E       = YOUNGS MODULUS OF ELASTICITY.
C  G       = SHEAR MODULUS OF ELASTICITY.
C  NEL     = FINITE ELEMENT NUMBER. FOR REFERENCE ONLY, NOT USED IN
C            CALCULATIONS. WRITTEN ON NUTMX, ETC.
C  J1      = JOINT NUMBER AT BAR END 1. LOCAL X-AXIS ORIGINATES AT J1.
C  J2      = JOINT NUMBER AT BAR END 2. LOCAL X-AXIS GOES FROM J1 TO J2.
C  JREF    = REFERENCE POINT. LOCAL Z-AXIS IS DEFINED BY VECTOR (J1,J2)
C            CROSSED INTO VECTOR (J1,JREF). LOCAL Y-AXIS LIES IN XY PLANE
C            DEFINED BY J1,J2,JREF.
C  A1      = CROSS-SECTION AREA AT BAR END 1.
C  A2      = SAME AS A1 AT BAR END 2.
C  PI1     = CROSS-SECTION POLAR AREA MOMENT OF INERTIA FOR MASS
C            CALCULATIONS AT BAR END 1.
C  PI2     = SAME AS PI1 AT BAR END 2.
C  TJ1     = CROSS-SECTION SAINT VENANTS TORSION CONSTANT (J) IN JG FOR
C            TORSION STIFFNESS AT BAR END 1.
C  TJ2     = SAME AS TJ1 AT BAR END 2.
C  BIZ1    = CROSS-SECTION AREA MOMENT OF INERTIA ABOUT LOCAL Z-AXIS
C            (FOR BENDING) AT BAR END 1.
C  BIZ2    = SAME AS BIZ1 AT BAR END 2.
C  BIY1    = CROSS-SECTION AREA MOMENT OF INERTIA ABOUT LOCAL Y-AXIS
C            (FOR BENDING) AT BAR END 1.
C  BIY2    = SAME AS BIY1 AT BAR END 2.
C  SF      = SHAPE FACTOR (K) FOR SHEAR IN KAG.
C            USE SF=0.0 FOR NO SHEAR DEFORMATION IN BENDING.
C            SF=1.0 FOR A SOLID CIRCULAR CYLINDER.
C            SF=.5 FOR A THIN WALLED CIRCULAR CYLINDER.
C  IFPY1   = PIN JOINT OPTION FOR LOCAL COORDINATE THETA Y AT BAR END 1.
C            = 1H , MOMENT JOINT.
C            = 1HP, PIN JOINT.
C  IFPY2   = SAME AS IFPY1 AT BAR END 2.
C  IFPZ1   = PIN JOINT OPTION FOR LOCAL COORDINATE THETA Z AT BAR END 1.
C            = 1H , MOMENT JOINT.
C            = 1HP, PIN JOINT.
C  IFPZ2   = SAME AS IFPZ1 AT BAR END 2.
C  IFTAPR  = OPTION FOR TAPERED BAR.
C            = 1H , CONSTANT SECTION PROPERTIES.
C            = 1HT, LINEAR TAPER SECTION PROPERTIES.
C  R1      = DISTANCE FROM LOCAL X-AXIS TO OUTER FIBER FOR TORSION
C            STRESS CALCULATION AT BAR END 1.
C  R2      = SAME AS R1 AT BAR END 2.
C  CY1     = DISTANCE FROM LOCAL XZ PLANE TO OUTER FIBER FOR BENDING
C            STRESS CALCULATION AT BAR END 1. LOCAL Y DIRECTION.
C  CY2     = SAME AS CY1 AT BAR END 2.
C  CZ1     = DISTANCE FROM LOCAL XY PLANE TO OUTER FIBER FOR BENDING
C            STRESS CALCULATION AT BAR END 1. LOCAL Z DIRECTION.
C  CZ2     = SAME AS CZ1 AT BAR END 2.
C
C  EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C     I = INTEGER DATA, RIGHT ADJUSTED.
C     E = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.
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```
C     X = CARD COLUMNS SKIPPED.
C   ****************************************************************************
C
C     SUBROUTINE ARGUMENTS (ALL INPUT)
C   XYZ    = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND
C            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C            X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
C   JDOF   = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C            TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C            ROTATION DOFS. SIZE(NJ,6).
C   EUL    = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C            GLOBAL X,Y,Z PERMUTATION. SIZE(NJ,3).
C   NUTEL  = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
C            THIS SUBROUTINE. IF NUTEL = 5, DATA IS READ FROM CARDS.
C   NJ     = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C   NUTMX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C            MASS MATRICES AND IVECS ARE OUTPUT.
C            NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C            USES FORTRAN READ, WRITE.
C   NUTKX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C            STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C            MATRICES) AND IVECS ARE OUTPUT.
C            NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C            USES FORTRAN READ, WRITE.
C   NUTBX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT UNIT LOAD
C            BUCKLING MATRICES AND IVECS ARE OUTPUT.
C            NUTBX MAY BE ZERO IF BUCKLING MATRIX IS NOT FORMED.
C            USES FORTRAN READ, WRITE.
C   NUTLT  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOCAL
C            LOAD TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C            NUTLT MAY BE ZERO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
C            USES FORTRAN READ, WRITE.
C   NUTST  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C            STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C            NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
C            USES FORTRAN READ, WRITE.
C   W      = MATRIX WORK SPACE. MIN SIZE(12,12).
C   T      = MATRIX WORK SPACE. MIN SIZE(12,12).
C   S      = MATRIX WORK SPACE. MIN SIZE(12,12).
C   KX     = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C   KJ     = ROW DIMENSION OF JDOF IN CALLING PROGRAM.
C   KE     = ROW DIMENSION OF EUL IN CALLING PROGRAM.
C   KW     = ROW DIMENSION OF W, T, AND S IN CALLING PROGRAM. MIN=12.
C
C     NERROR  EXPLANATION
C   1 = JOINT NUMBER GREATER THAN NUMBER OF JOINTS.
C   2 = STIFFNESS MATRIX FORMED, NUTKX .LE. ZERO.
C   3 = LOAD TRANSFORMATION MATRIX FORMED, NUTLT .LE. ZERO.
C   4 = STRESS TRANSFORMATION MATRIX FORMED, NUTST .LE. ZERO.
C   5 = MASS MATRIX FORMED, NUTMX .LE. ZERO.
C   6 = BUCKLING MATRIX FORMED, NUTBX .LE. ZERO.
C
 1001 FORMAT (5(A6,4X),A1,A1,A2,A2, 4X A2,A2)
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 1002 FORMAT (3(5X,E10.0))
 1003 FORMAT (4I5,5E10.0,E5.0,5A1)
 1004 FORMAT (20X,6E10.0)
 2001 FORMAT (//46X 27HINPUT DATA FOR BAR ELEMENTS)
 2002 FORMAT (//40X 39HINPUT DATA FOR BAR ELEMENTS (CONTINUED))
 2003 FORMAT (  45X,8HKODEK = A1,A1,A2,A2, 4X 8HKODEB = A2,A2,
     *          / 10X7HMASS = A6, 6X7HSTIF = A6, 6X13HLOAD TRANS = A6,
     *            3X15HSTRESS TRANS = A6. 3X11HBUCKLING = A6,
     *          / 12X4HRO = E10.3, 6X3HE = E10.3, 80X7HI I I I,
     *          / 32X3HG = E10.3, 80X7HF F F F,
     *          / 125X7HP P P P,
     *          / 1X7HELEMENT 2X5HJOINT   2X5HJOINT   3X3HREF 5X4HAREA
     *            7X5HPOLAR 5X7HTORSION 3X9HZ BENDING 2X9HY BENDING
     *            2X5HSHEAR 3X6HSTRESS 5X6HSTRESS 5X6HSTRESS 3X7HY Z Y Z
     *          / 1X6HNUMBER 5X1H1 6X1H2 4X5HPOINT
     *            14X 7HINERTIA 5X5HCONST 5X7HINERTIA
     *            4X7HINERTIA 3X6HFACTOR 5X1HR 9X2HCY 9X2HCZ 5X7H1 1 2 2/)
 2004 FORMAT (1X I5, I8, 2I7, 1X 5E11.3, F7.3, 3E11.3, 4(1XA1))
 2005 FORMAT (29X,5E11.3,7X,3E11.3)
C
C  READ AND WRITE FINITE ELEMENT DATA.
      R1 = 0.0
      CY1 = 0.0
      CZ1 = 0.0
      NLINE = 0
      CALL PAGEHD
      WRITE (NOT,2001)
      READ (NUTEL,1001) NAMEM,NAMEK,NAMELT,NAMEST,NAMEB,
     *                  (KODEK(I),I=1,4),(KODEB(I),I=1,2)
      READ (NUTEL,1002) RO,E,G
      WRITE (NOT,2003) (KODEK(I),I=1,4),(KODEB(I),I=1,2),
     *                  NAMEM,NAMEK,NAMELT,NAMEST,NAMEB,RO,E,G
   20 READ (NUTEL,1003) NEL,J1,J2,JREF,A1,PI1,TJ1,BIZ1,BIY1,SF,
     *                  IFPIN,IFTAPR
      IF (J1 .LE. 0) RETURN
      IF (IFTAPR .EQ. 1HT) READ (NUTEL,1004) A2,PI2,TJ2,BIZ2,BIY2
      IF (NAMEST .EQ. 6H       .OR. NAMEST .EQ. 6HNOSTRS) GO TO 25
      READ (NUTEL,1004) R1,CY1,CZ1,R2,CY2,CZ2
   25 NLINE = NLINE + 1
      IF (IFTAPR .EQ. 1HT) NLINE=NLINE+1
      IF (NLINE .LE. 42) GO TO 30
      CALL PAGEHD
      WRITE (NOT,2002)
      WRITE (NOT,2003) (KODEK(I),I=1,4),(KODEB(I),I=1,2),
     *                  NAMEM,NAMEK,NAMELT,NAMEST,NAMEB,RO,E,G
      NLINE = 0
   30 WRITE (NOT,2004) NEL,J1,J2,JREF,A1,PI1,TJ1,BIZ1,BIY1,SF,
     *                  R1,CY1,CZ1,IFPIN
                                                                  NERROR=1
      IF (J1 .GT. NJ .OR. J2 .GT. NJ .OR. JREF .GT. NJ) GO TO 999
      IF (IFTAPR .EQ. 1HT) WRITE (NOT,2005) A2,PI2,TJ2,BIZ2,BIY2,R2,
     *                                      CY2,CZ2
C
C  FORM FINITE ELEMENT COORDINATE LOCATIONS, EULER ANGLES, REVADD IVEC.
      DO 42 I=1,3
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      CJ(I,1) = XYZ(J1,I)
      CJ(I,2) = XYZ(J2,I)
      CJ(I,3) = XYZ(JREF,I)
      EJ(I,1) = EUL(J1,I)
   42 EJ(I,2) = EUL(J2,I)
      DO 44 I=1,6
      IV1(I)    = JDOF(J1,I)
   44 IV1(I+6) = JDOF(J2,I)
C
C  FORM DATA FOR UNIFORM ELEMENT.
      IF (IFTAPR .EQ. 1HT) GO TO 50
      A2 = A1
      PI2 = PI1
      TJ2 = TJ1
      BIZ2 = BIZ1
      BIY2 = BIY1
      R2 = R1
      CY2 = CY1
      CZ2 = CZ1
C
C  FORM PINING IVEC.
   50 NPIN = 0
      DO 55 I=1,4
      IF (IFPIN(I) .NE. 1HP) GO TO 55
      NPIN = NPIN + 1
      IF (I .EQ. 1) IV2(NPIN) = 11
      IF (I .EQ. 2) IV2(NPIN) = 7
      IF (I .EQ. 3) IV2(NPIN) = 12
      IF (I .EQ. 4) IV2(NPIN) = 8
   55 CONTINUE
C
C  FORM STIFFNESS MATRIX (W), LOCAL LOAD TRANSFORMATION MATRIX (T),
C  STRESS TRANSFORMATION MATRIX (S).
  100 IF (NAMEK .EQ. 6H       .OR. NAMEK .EQ. 6HNOSTIF) GO TO 110
      CALL STF1B  (CJ,EJ,KODEK,A1,A2,TJ1,TJ2,BIZ1,BIZ2,BIY1,BIY2,R1,R2,
     *             CY1,CY2,CZ1,CZ2,SF,E,G,NAMEK,NAMEST,W,T,S,NRST,
     *             KCJ,KCJ,KW,KW,KW)
C
C  PIN STIFFNESS MATRIX.
      IF (NPIN .EQ. 0) GO TO 105
      CALL DCOS1B (CJ,EJ,W,KCJ,KCJ,KW)
      CALL TRANS  (W,TR,NRW,NRW,KW,KTR)
      CALL MULTA  (T,TR,NRLT,NRW,NRW,KW,KTR)
      CALL SRED3  (T,IV2,T,TD,NRW,NPIN,1,KW)
      CALL MULTA  (TD,W,NRW,NRW,NRW,KTD,KW)
      CALL MULTA  (TR,TD,NRW,NRW,NRW,KTR,KTD)
      CALL MULTA  (T,W,NRLT,NRW,NRW,KW,KW)
      CALL ATXBA1 (W,T,NRW,NRW,KW,KW)
      IF (NAMEST .EQ. 6H       .OR. NAMEST .EQ. 6HNOSTRS) GO TO 105
      CALL MULTA  (S,TR,NRST,NRW,NRW,KW,KTR)
  105                                                            NERROR=2
      IF (NUTKX .LE. 0) GO TO 999
      WRITE (NUTKX) NAMEK,NEL,NRW,NRW,NAMEL,(IBLNK,I=1,5),
     *              ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
      IF (NAMELT .EQ. 6H       .OR. NAMELT .EQ. 6HNOLOAD) GO TO 115
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                                                              NERROR=3
      IF (NUTLT .LE. 0) GO TO 999
      WRITE (NUTLT) NAMELT,NFL,NRLT,NRW,NAMEL,(IBLNK,I=1,5),
     *               ((T(I,J),I=1,NRLT),J=1,NRW),(IV1(I),I=1,NRW)
  115 IF (NAMEST .EQ. 6H       .OR. NAMEST .EQ. 6HNOSTRS) GO TO 110
                                                              NERROR=4
      IF (NUTST .LE. 0) GO TO 999
      WRITE (NUTST) NAMEST,NEL,NRST,NRW,NAMEL,(IBLNK,I=1,5),
     *               ((S(I,J),I=1,NRST),J=1,NRW),(IV1(I),I=1,NRW)
C
C  FORM MASS MATRIX (W).
  110 IF (NAMEM .EQ. 6H       .OR. NAMEM .EQ. 6HNOMASS) GO TO 140
      CALL MAS1B  (CJ,EJ,A1,A2,PI1,PI2,RO,NAMEM,W,T,KCJ,KCJ,KW,KW)
C
C  PIN MASS MATRIX.
      IF (NPIN .GT. 0) CALL BTABA  (W,TR,NRW,NRW,KW,KTR)
                                                              NERROR=5
      IF (NUTMX .LE. 0) GO TO 999
      WRITE (NUTMX) NAMEM,NEL,NRW,NRW,NAMEL,(IBLNK,I=1,5),
     *               ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
C
C  FORM UNIT LOAD BUCKLING MATRIX (W).
  140 IF (NAMEB .EQ. 6H       .OR. NAMEB .EQ. 6HNOBUCK) GO TO 20
      CALL BUC1B  (CJ,EJ,KODEB,NAMEB,W,S,KCJ,KCJ,KW,KW)
                                                              NERROR=6
      IF (NUTBX .LE. 0) GO TO 999
      WRITE (NUTBX) NAMEB,NEL,NRW,NRW,NAMEL,(IBLNK,I=1,5),
     *               ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
      GO TO 20
C
  999 CALL ZZBOMB (6HBAR   ,NERROR)
      END
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      SUBROUTINE BUC1B  (CJ,EJ,KODEB,NAMEB,Z,W,KCJ,KEJ,KZ,KW)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), KODEB(1), Z(KZ,1), W(KW,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     BUCKLING MATRIX
C  FOR A COMBINED AXIAL-TORSION-BENDING BAR ELEMENT WITH UNRESTRAINED
C  BOUNDARIES.
C  BUCKLING MATRIX IS BASED ON UNIT AXIAL LOAD.
C  BUCKLING MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C  GLOBAL COORDINATE ORDER IS
C     (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2
C  WHERE U,V,W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS.
C  EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C  CALLS FORMA SUBROUTINES B1A1, B1A2, BTABA, DCOS1B, ZZBOMB.
C  DEVELOPED BY  RL WOHLEN.  AUGUST 1973.
C  LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C     SUBROUTINE ARGUMENTS
C  CJ      = INPUT  MATRIX OF GLOBAL X,Y,Z COORDINATES AT BAR JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C                   COLS 1,2 CORRESPOND TO JOINTS 1,2. COL 3 CORRESPONDS
C                   TO REFERENCE POINT TO DEFINE LOCAL XY PLANE. SIZE(3,3).
C  EJ      = INPUT  MATRIX OF EULER ANGLES (DEGREES) AT BAR JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C                   COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C  KODEB   = INPUT  OPTION CODE FOR LOCAL Y, LOCAL Z BUCKLING.
C                   IF BLANK, BOTH ARE CALCULATED. SIZE(2).
C                   KODEB(1)=BY, LOCAL BUCKLING MATRIX IS CALCULATED
C                             FOR LOCAL Y DIRECTION.
C                   KODEB(2)=BZ, LOCAL BUCKLING MATRIX IS CALCULATED
C                             FOR LOCAL Z DIRECTION.
C  NAMEB   = INPUT  TYPE OF BUCKLING MATRIX WANTED.
C                   =B1, AXIAL ROD.
C                   =B2, BEAM.
C  Z       = OUTPUT BUCKLING MATRIX. SIZE(12,12).
C  W       = INPUT  WORK SPACE MATRIX. SIZE(12,12).
C  KCJ     = INPUT  ROW DIMENSION OF CJ IN CALLING PROGRAM.
C  KEJ     = INPUT  ROW DIMENSION OF EJ IN CALLING PROGRAM.
C  KZ      = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=12.
C  KW      = INPUT  ROW DIMENSION OF W IN CALLING PROGRAM. MIN=12.
C
C     NERROR  EXPLANATION
C  1 = DIMENSION SIZE EXCEEDED.
C  2 = IMPROPERLY DEFINED NAMEB.
C
                                                               NERROR=1
      IF (KZ .LT. 12 .OR. KW .LT. 12) GO TO 999
      DO 5 J=1,12
      DO 5 I=1,12
    5 Z(I,J) = 0.0
      RL = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
     *                               + (CJ(3,2)-CJ(3,1))**2)
      KODEBY = 1
      KODEBZ = 1
      IF (KODEB(1).EQ.2H  .AND. KODEB(2).EQ.2H  ) GO TO 10
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      IF (KODEB(1) .NE. 2HBY) KODEBY = 0
      IF (KODEB(2) .NE. 2HBZ) KODEBZ = 0
   10 IF (NAMEB .EQ. 6HB1     ) GO TO 110
      IF (NAMEB .EQ. 6HB2     ) GO TO 120                          NERROR=2
      GO TO 999
C
  110 IF (KODEBY .EQ. 1) CALL B1A1 (RL,Z(5,5),KZ)
      IF (KODEBZ .EQ. 1) CALL B1A1 (RL,Z(9,9),KZ)
      GO TO 300
C
  120 IF (KODEBY .EQ. 1) CALL B1A2 (RL,Z(5,5),KZ)
      DO 125 J=7,8
      DO 125 I=5,6
      Z(I,J) =-Z(I,J)
  125 Z(J,I) =-Z(J,I)
      IF (KODEBZ .EQ. 1) CALL B1A2 (RL,Z(9,9),KZ)
C
  300 CALL DCOS1B (CJ,EJ,W,KCJ,KEJ,KW)
      CALL PTABA  (Z,W, 12,12, KZ,KW)
      RETURN
C
  999 CALL ZZBOMB (6HBUC1B ,NERROR)
      END
```

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      SUBROUTINE DCOS1A (CJ,EJ,Z,KCJ,KEJ,KZ)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(KZ,1)
      DIMENSION P(3), T(3,3)
C
C   SUBROUTINE TO CALCULATE FINITE ELEMENT...
C      DIRECTION COSINE MATRIX
C   FOR AN AXIAL ROD ELEMENT.
C   THE DIRECTION COSINE MATRIX RELATES LOCAL COORDINATE DISPLACEMENTS
C   TO GLOBAL COORDINATE DISPLACEMENTS.
C   THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C   WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C   ROW ORDER (LOCAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
C      DX1,DX2
C   WHERE DX IS TRANSLATION.
C   COLUMN ORDER (GLOBAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
C      (U,V,W) JOINT 1, THEN JOINT 2.
C   WHERE U,V,W ARE TRANSLATIONS.
C   EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C   CALLS FORMA SUBROUTINES EULER,MULTB,ZZBOMB.
C   DEVELOPED BY RL WOHLEN.  SEPTEMBER 1972.
C   LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C      SUBROUTINE ARGUMENTS
C   CJ      = INPUT  MATRIX OF GLOBAL X,Y,Z COORDINATES AT ROD JOINTS.
C                    ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C                    COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C   EJ      = INPUT  MATRIX OF EULER ANGLES (DEGREES) AT ROD JOINTS.
C                    ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C                    COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C   Z       = OUTPUT DIRECTION COSINE MATRIX. SIZE(2,6).
C   KCJ     = INPUT  ROW DIMENSION OF CJ IN CALLING PROGRAM.
C   KEJ     = INPUT  ROW DIMENSION OF EJ IN CALLING PROGRAM.
C   KZ      = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C
C      NERROR  EXPLANATION
C   1 = DIMENSION SIZE LESS THAN 2.
C
                                                             NERROR = 1
      IF (KZ .LT. 2) GO TO 999
      PX = CJ(1,2)-CJ(1,1)
      PY = CJ(2,2)-CJ(2,1)
      PZ = CJ(3,2)-CJ(3,1)
      PL = SQRT(PX**2 + PY**2 + PZ**2)
      P(1) = PX/PL
      P(2) = PY/PL
      P(3) = PZ/PL
      DO 10 I=1,2
      DO 10 J=1,6
   10 Z(I,J) = 0.0
      CALL EULER  (EJ(1,1),T,3)
      CALL MULTB  (P,T, 1,3,3, 1,3)
      DO 22 J=1,3
   22 Z(1,J) = T(1,J)
      CALL EULER  (EJ(1,2),T,3)
      CALL MULTB  (P,T, 1,3,3, 1,3)
```

```
      DO 24 J=1,3
   24 Z(2,J+3) = T(1,J)
      RETURN
C
  999 CALL ZZ6OMB (6HDCOS1A,NERROR)
      END
```

```
      SUBROUTINE DCOS1B (CJ,EJ,Z,KCJ,KEJ,KZ)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(KZ,1)
      DIMENSION W(3,3), T(3,3)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     DIRECTION COSINE MATRIX
C  FOR A COMBINED AXIAL-TORSION-BENDING BAR ELEMENT.
C  THE DIRECTION COSINE MATRIX RELATES LOCAL COORDINATE DISPLACEMENTS
C  TO GLOBAL COORDINATE DISPLACEMENTS.
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE BAR TO LIE IN THE X-Y PLANE
C  WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS,
C  REFERENCE POINT 3 (TO DEFINE THE LOCAL X-Y PLANE) IS IN THE
C  POSITIVE Y DIRECTION.
C  ROW ORDER (LOCAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
C     DX1,DX2, TX1,TX2, DY1,DY2,TZ1,TZ2, DZ1,DZ2,TY1,TY2
C  WHERE DX,DY,DZ ARE TRANSLATIONS AND TX,TY,TZ ARE ROTATIONS.
C  COLUMN ORDER (GLOBAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
C     (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2
C  WHERE U,V,W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS.
C  EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C  CALLS FORMA SUBROUTINES EULER,MULTB,ZZBOMB.
C  DEVELOPED BY RL WOHLEN.  FEBRUARY 1973.
C  LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C     SUBROUTINE ARGUMENTS
C  CJ     = INPUT  MATRIX OF GLOBAL X,Y,Z COORDINATES AT BAR JOINTS.
C                  ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C                  COLS 1,2 CORRESPOND TO JOINTS 1,2. COL 3 CORRESPONDS
C                  TO REFERENCE POINT TO DEFINE LOCAL XY PLANE. SIZE(3,3).
C  EJ     = INPUT  MATRIX OF EULER ANGLES (DEGREES) AT BAR JOINTS.
C                  ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C                  COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C  Z      = OUTPUT DIRECTION COSINE MATRIX. SIZE(12,12).
C  KCJ    = INPUT  ROW DIMENSION OF CJ IN CALLING PROGRAM.
C  KEJ    = INPUT  ROW DIMENSION OF EJ IN CALLING PROGRAM.
C  KZ     = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=12.
C
C     NERROR  EXPLANATION
C  1 = DIMENSION SIZE LESS THAN 12.
C
                                                          NERROR = 1
      IF (KZ .LT. 12) GO TO 999
      PX = CJ(1,2)-CJ(1,1)
      PY = CJ(2,2)-CJ(2,1)
      PZ = CJ(3,2)-CJ(3,1)
      PL = SQRT(PX**2 + PY**2 + PZ**2)
      RX = PY*(CJ(3,3)-CJ(3,1)) - PZ*(CJ(2,3)-CJ(2,1))
      RY = PZ*(CJ(1,3)-CJ(1,1)) - PX*(CJ(3,3)-CJ(3,1))
      RZ = PX*(CJ(2,3)-CJ(2,1)) - PY*(CJ(1,3)-CJ(1,1))
      RL = SQRT(RX**2 + RY**2 + RZ**2)
      QX = RY*PZ - RZ*PY
      QY = RZ*PX - RX*PZ
      QZ = RX*PY - RY*PX
      QL = SQRT(QX**2 + QY**2 + QZ**2)
      W(1,1) = PX/PL
```

```
      W(1,2) = PY/PL
      W(1,3) = PZ/PL
      W(2,1) = QX/QL
      W(2,2) = QY/QL
      W(2,3) = QZ/QL
      W(3,1) = RX/RL
      W(3,2) = RY/RL
      W(3,3) = RZ/RL
      DO 10 J=1,12
      DO 10 I=1,12
   10 Z(I,J) = 0.0
      CALL EULER  (EJ(1,1),T,3)
      CALL MULTB  (W,T, 3,3,3, 3,3)
      DO 22 J=1,3
      Z(1,J) = T(1,J)
      Z(5,J) = T(2,J)
      Z(9,J) = T(3,J)
      JP3 = J+3
      Z( 3,JP3) = T(1,J)
      Z( 7,JP3) = T(3,J)
   22 Z(11,JP3) = T(2,J)
      CALL EULER  (EJ(1,2),T,3)
      CALL MULTB  (W,T, 3,3,3, 3,3)
      DO 24 J=1,3
      JP6 = J+6
      Z( 2,JP6) = T(1,J)
      Z( 6,JP6) = T(2,J)
      Z(10,JP6) = T(3,J)
      JP9 = J+9
      Z( 4,JP9) = T(1,J)
      Z( 8,JP9) = T(3,J)
   24 Z(12,JP9) = T(2,J)
      RETURN
C
  999 CALL ZZBOMB (6HDCOS1B,NERROR)
      END
```

```
      SUBROUTINE DCOS2  (CJ,EJ,Z,KCJ,KEJ,KZ)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(KZ,1)
      DIMENSION W(3,3), T(3,3)
C
C   SUBROUTINE TO CALCULATE FINITE ELEMENT...
C      DIRECTION COSINE MATRIX
C   FOR A COMBINED MEMBRANE-BENDING TRIANGLE PLATE ELEMENT.
C   THE DIRECTION COSINE MATRIX RELATES LOCAL COORDINATE DISPLACEMENTS
C   TO GLOBAL COORDINATE DISPLACEMENTS.
C   THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
C   WITH JOINT 1 AT THE ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C   X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
C   ROW ORDER (LOCAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
C      (DX,DY,TZ) JOINT 1, THEN JOINT 2, 3, NEXT
C      (DZ,TX,TY) JOINT 1, THEN JOINT 2, 3
C   WHERE DX,DY,DZ ARE TRANSLATIONS AND TX,TY,TZ ARE ROTATIONS.
C   COLUMN ORDER (GLOBAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
C      (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2, 3.
C   WHERE U,V,W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS.
C   EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C   CALLS FORMA SUBROUTINES EULER,MULTB,ZZBOMB.
C   DEVELOPED BY WA BENFIELD. FEBRUARY 1973.
C   LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C      SUBROUTINE ARGUMENTS
C   CJ      = INPUT  MATRIX OF GLOBAL X,Y,Z COORDINATES AT TRIANGLE JOINTS.
C                    ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C                    COLS 1,2,3 CORRESPEOND TO JOINTS 1,2,3. SIZE(3,3).
C   EJ      = INPUT  MATRIX OF EULER ANGLES (DEGREES) AT TRIANGLE JOINTS.
C                    ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C                    COLS 1,2,3 CORRESPEOND TO JOINTS 1,2,3. SIZE(3,3).
C   Z       = OUTPUT DIRECTION COSINE MATRIX. SIZE(18,18).
C   KCJ     = INPUT  ROW DIMENSION OF CJ IN CALLING PROGRAM.
C   KEJ     = INPUT  ROW DIMENSION OF EJ IN CALLING PROGRAM.
C   KZ      = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=18.
C
C      NERROR  EXPLANATION
C   1 = DIMENSION SIZE LESS THAN 18.
C
                                                                 NERROR=1
      IF (KZ .LT. 18) GO TO 999
      PX = CJ(1,2)-CJ(1,1)
      PY = CJ(2,2)-CJ(2,1)
      PZ = CJ(3,2)-CJ(3,1)
      PL = SQRT(PX**2 + PY**2 + PZ**2)
      RX = PY*(CJ(3,3)-CJ(3,1)) - PZ*(CJ(2,3)-CJ(2,1))
      RY = PZ*(CJ(1,3)-CJ(1,1)) - PX*(CJ(3,3)-CJ(3,1))
      RZ = PX*(CJ(2,3)-CJ(2,1)) - PY*(CJ(1,3)-CJ(1,1))
      RL = SQRT(RX**2 + RY**2 + RZ**2)
      QX = RY*PZ - RZ*PY
      QY = RZ*PX - RX*PZ
      QZ = RX*PY - RY*PX
      QL = SQRT(QX**2 + QY**2 + QZ**2)
      W(1,1) = PX/PL
      W(1.2) = PY/PL
```

```
      W(1,3) = PZ/PL
      W(2,1) = QX/QL
      W(2,2) = QY/QL
      W(2,3) = QZ/QL
      W(3,1) = RX/RL
      W(3,2) = RY/RL
      W(3,3) = RZ/RL
      DO 10 J=1,18
      DO 10 I=1,18
   10 Z(I,J) = 0.0
      DO 50 NW=1,3
      CALL EULER  (EJ(1,NW),T,3)
      CALL MULTE  (W,T, 3,3,3, 3,3)
      IZZ = 3*(NW-1)
      JZZ = 6*(NW-1)
      DO 50 JW=1,3
      JZ = JZZ+JW
      Z(IZZ+ 1,JZ) = T(1,JW)
      Z(IZZ+ 2,JZ) = T(2,JW)
      Z(IZZ+10,JZ) = T(3,JW)
      JZ = JZ+3
      Z(IZZ+ 3,JZ) = T(3,JW)
      Z(IZZ+11,JZ) = T(1,JW)
   50 Z(IZZ+12,JZ) = T(2,JW)
      RETURN
C
  999 CALL ZZBOMB (6HDCOS2 ,NERROR)
      END
```

```
      SUBROUTINE DCOS3C (CJ,EJ,Z,KCJ,KEJ,KZ)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(KZ,1)
      DIMENSION W(2,3), T(3,3)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     DIRECTION COSINE MATRIX
C  FOR A RECTANGULAR SHEAR PANEL ELEMENT.
C  THE DIRECTION COSINE MATRIX RELATES LOCAL COORDINATE DISPLACEMENTS
C  TO GLOBAL COORDINATE DISPLACEMENTS.
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE PANEL TO LIE IN AN X-Y PLANE
C  WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C  X AXIS, JOINT 3 IS IN THE POSITIVE X,Y DIRECTION, AND JOINT 4 LIES
C  ALONG THE POSITIVE Y AXIS.
C  ROW ORDER (LOCAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
C     DX1,DX2,DX3,DX4, DY1,DY2,DY3,DY4
C  WHERE DX,DY ARE TRANSLATIONS.
C  COLUMN ORDER (GLOBAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
C     (U,V,W) JOINT 1, THEN JOINT 2, 3, 4.
C  WHERE U,V,W ARE TRANSLATIONS.
C  EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C  CALLS FORMA SUBROUTINES EULER,MULTB,ZZBOMB.
C  DEVELOPED BY  RL WOHLEN. APRIL 1974.
C  LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C     SUBROUTINE ARGUMENTS
C  CJ      = INPUT  MATRIX OF GLOBAL X,Y,Z COORDINATES AT PANEL JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C                   COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C  EJ      = INPUT  MATRIX OF EULER ANGLES (DEGREES) AT PANEL JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C                   COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C  Z       = OUTPUT DIRECTION COSINE MATRIX. SIZE(8,12).
C  KCJ     = INPUT  ROW DIMENSION OF CJ IN CALLING PROGRAM.
C  KEJ     = INPUT  ROW DIMENSION OF EJ IN CALLING PROGRAM.
C  KZ      = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=8.
C
C     NERROR  EXPLANATION
C  1 = DIMENSION SIZE TOO SMALL.
C
                                                              NERROR=1
      IF (KZ .LT. 8) GO TO 999
      PX = CJ(1,2)-CJ(1,1)
      PY = CJ(2,2)-CJ(2,1)
      PZ = CJ(3,2)-CJ(3,1)
      PL = SQRT(PX**2 + PY**2 + PZ**2)
      QX = CJ(1,4)-CJ(1,1)
      QY = CJ(2,4)-CJ(2,1)
      QZ = CJ(3,4)-CJ(3,1)
      QL = SQRT(QX**2 + QY**2 + QZ**2)
      W(1,1) = PX/PL
      W(1,2) = PY/PL
      W(1,3) = PZ/PL
      W(2,1) = QX/QL
      W(2,2) = QY/QL
      W(2,3) = QZ/QL
```

```
      DO 10 J=1,12
      DO 10 I=1,8
   10 Z(I,J) = 0.0
      DO 50 IJNT=1,4
      CALL EULER  (EJ(1,IJNT),T,3)
      CALL MULTE  (W,T, 2,3,3, 2,3)
      JZZ = 3*(IJNT-1)
      DO 50 JW=1,3
      JZ = JZZ+JW
      Z(IJNT  ,JZ) = T(1,JW)
   50 Z(IJNT+4,JZ) = T(2,JW)
      RETURN
C
  999 CALL ZZBOMB (6HDCOS3C,NERROR)
      END
```

```
      SUBROUTINE EULER (E,R,KR)
      DIMENSION E(1),R(KR,1)
C
C  CALCULATE EULER ANGLE ROTATION TRANSFORMATION MATRIX.
C  EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C  DEVELOPED BY C  BODLEY. MARCH 1973.
C
C     SUBROUTINE ARGUMENTS
C  E       = INPUT  VECTOR OF JOINT EULER ANGLES (DEGREES).
C                   LOCATIONS 1,2,3 CORRESPOND TO THE GLOBAL X,Y,Z
C                   PERMUTATION. SIZE(3).
C  R       = OUTPUT EULER ROTATION TRANSFORMATION MATRIX. SIZE(3,3).
C  KR      = INPUT  ROW DIMENSION OF R IN CALLING PROGRAM.
C
      DTOR = ATAN2(1.,1.)/45.
C
      C1 = COS(E(1)*DTOR)
      C2 = COS(E(2)*DTOR)
      C3 = COS(E(3)*DTOR)
      S1 = SIN(E(1)*DTOR)
      S2 = SIN(E(2)*DTOR)
      S3 = SIN(E(3)*DTOR)
C
      R(1,1) =  C2*C3
      R(1,2) = -C2*S3
      R(1,3) =  S2
      R(2,1) =  C1*S3 + S1*S2*C3
      R(2,2) =  C1*C3 - S1*S2*S3
      R(2,3) = -S1*C2
      R(3,1) =  S1*S3 - C1*S2*C3
      R(3,2) =  S1*C3 + C1*S2*S3
      R(3,3) =  C1*C2
C
      RETURN
      END
```

```
      SUBROUTINE FINEL  (XYZ,JDOF,EUL,NUTEL,NJ,
     *                  NUTM,NUTK,NUTLT,NUTST,NUTB,V,LV,KV,
     *                  KRX,KRJ,KRE,NUTMX,NUTKX,NUT1,NUT2,NUT3)
      DIMENSION XYZ(KRX,1), JDOF(KRJ,1), EUL(KRE,1), V(1), LV(1)
      DIMENSION W1(24,24), W2(24,24), W3(24,24)
      DATA KW/24/, IBLANK/6H      /, I1/1/
      DATA NIT,NOT/5,6/
C
C  SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT...
C     ASSEMBLED MASS MATRIX (ON NUTM),
C     ASSEMBLED STIFFNESS MATRIX (ON NUTK),
C     ELEMENT LOCAL LOAD TRANSFORMATION MATRICES, IVECS (ON NUTLT),
C     ELEMENT GLOBAL LOAD TRANSFORMATION MATRICES, IVECS (ON NUTKX),
C     ELEMENT STRESS TRANSFORMATION MATRICES, IVECS (ON NUTST),
C     ELEMENT UNIT LOAD BUCKLING MATRICES, IVECS (ON NUTB).
C  IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
C     IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C     IVEC(3)=0   OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINS
C                 ELEMENT DOF 3 TO ZERO MOTION.
C  DATA ARRANGEMENT ON NUTM, NUTK FOR THE ASSEMBLED MATRICES IS IN
C  SPARSE (Y) FORMA SUBROUTINE FORMAT.
C  DATA ARRANGEMENT ON NUTLT, NUTKX, NUTST, NUTB FOR EACH FINITE
C  ELEMENT (WRITTEN IN SUBROUTINE AXIAL, BAR, ETC) IS
C     WRITE (NUTW) NAMEW,NEL,NR,NC,NAMEL (IBLANK,I=1,5),
C                 ((W(I,J),I=1,NR),J=1,NC),(IVEC(I),I=1,NC)
C     NAMEW = NAMELT,NAMEKX,NAMEST, OR NAMEB.
C     NAMEL = AXIAL,BAR,ETC.
C  LAST RECORD (TO DENOTE TERMINATION) IS,
C     WRITE (NUTW) IBLANK,(I1,I=1,30)
C  THE FOLLOWING UTILITY TAPES USE BASIC FORTRAN READ, WRITE. DO NOT
C  USE THESE TAPES IN SPARSE (Y) FORMA SUBROUTINES WHICH USE FORMA
C  SUBROUTINES YIN, YOUT (BECAUSE THEY USE BUFFER IN, BUFFER OUT).
C     NUTLT, NUTST, NUTMX, NUTKX, NUTB.
C  THE FOLLOWING UTILITY TAPES USE FORMA YIN, YOUT.
C     NUTM, NUTK, NUT1, NUT2, NUT3.
C  CALLS FORMA SUBROUTINES AXIAL ,BAR   ,FLUID ,GRAVTY,PAGEHD,QUAD  ,
C                          RECTSP,TRNGL ,YRVAD2,ZZBCMB.
C  DEVELOPED BY WA BENFIELD, CS BODLEY, RL WOHLEN. JANUARY 1973.
C  LAST REVISION BY  RL WOHLEN.  MAY 1976.
C
C  ***********************************************************************
C  INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = 5, DATA IS
C  READ FROM CARDS.
C  50 NAMEL                                           FORMAT (A6)
C     IF (NAMEL .EQ. 6HRETURN) RETURN
C     IF (NAMEL .EQ. 6HAXIAL ) CALL AXIAL  (SEE SUBRT FOR INPUT)
C     IF (NAMEL .EQ. 6HBAR   ) CALL BAR    (SEE SUBRT FOR INPUT)
C     IF (NAMEL .EQ. 6HFLUID ) CALL FLUID  (SEE SUBRT FOR INPUT)
C     IF (NAMEL .EQ. 6HGRAVTY) CALL GRAVTY (SEE SUBRT FOR INPUT)
C     IF (NAMEL .EQ. 6HQUAD  ) CALL QUAD   (SEE SUBRT FOR INPUT)
C     IF (NAMEL .EQ. 6HRECTSP) CALL RECTSP (SEE SUBRT FOR INPUT)
C     IF (NAMEL .EQ. 6HTRNGL ) CALL TRNGL  (SEE SUBRT FOR INPUT)
C     GO TO 50
C
C  DEFINITION OF INPUT VARIABLES.
```

```
C  NAMEL  = AXIAL, BAR, ETC AS SHOWN ABOVE. GIVES SUBROUTINE CALLED.
C
C  EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C     A = ANY KEYPUNCH SYMBOL.
C     X = CARD COLUMNS SKIPPED.
C  ***********************************************************************
C
C     SUBROUTINE ARGUMENTS (ALL INPUT)
C  XYZ    = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND
C           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C           X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
C           MAY BE EQUIVALENCED TO V(1) IN CALLING PROGRAM.
C  JDOF   = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C           TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C           ROTATION DOFS. SIZE(NJ,6).
C           MAY BE EQUIVALENCED TO LV(1) IN CALLING PROGRAM.
C  EUL    = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C           GLOBAL X,Y,Z PERMUTATION. SIZE(NJ,3). MAY BE
C           EQUIVALENCED TO V(KRX*(XYZ COL DIM)+1) IN CALLING PROGRAM.
C  NUTEL  = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
C           THIS SUBROUTINE AND SUBROUTINES AXIAL, ETC GIVEN BY NAMEL.
C           IF NUTEL = 5, DATA WILL BE READ FROM CARDS.
C  NJ     = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C  NUTM   = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ASSEMBLED
C           MASS MATRIX IS OUTPUT IN SPARSE NOTATION.
C           NUTM MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C           USES FORMA YIN, YOUT.
C  NUTK   = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ASSEMBLED
C           STIFFNESS MATRIX IS OUTPUT IN SPARSE NOTATION.
C           NUTK MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C           USES FORMA YIN, YOUT.
C  NUTLT  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOCAL
C           LOAD TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C           NUTLT MAY BE ZERO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
C           USES FORTRAN READ, WRITE.
C  NUTST  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C           STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C           NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
C           USES FORTRAN READ, WRITE.
C  NUTB   = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT UNIT LOAD
C           BUCKLING MATRICES AND IVECS ARE OUTPUT.
C           NUTB MAY BE ZERO IF BUCKLING MATRICES ARE NOT FORMED.
C           USES FORTRAN READ, WRITE.
C  V      = VECTOR WORK SPACE.
C  LV     = VECTOR WORK SPACE.
C  KV     = DIMENSION SIZE OF V,LV IN CALLING PROGRAM.
C  KRX    = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C  KRJ    = ROW DIMENSION OF JDOF IN CALLING PROGRAM.
C  KRE    = ROW DIMENSION OF EUL IN CALLING PROGRAM.
C  NUTMX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C           MASS MATRICES AND IVECS ARE STORED.
C           NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C           USES FORTRAN READ, WRITE.
```

```
C  NUTKX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C           STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C           MATRICES) AND IVECS ARE STORED.
C           NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C           USES FORTRAN READ, WRITE.
C  NUT1   = LOGICAL NUMBER OF UTILITY TAPE. USES FORMA YIN, YOUT.
C  NUT2   = LOGICAL NUMBER OF UTILITY TAPE. USES FORMA YIN, YOUT.
C  NUT3   = LOGICAL NUMBER OF UTILITY TAPE. USES FORMA YIN, YOUT.
C
C      NERROR  EXPLANATION
C  1 = NAMEL IMPROPERLY DEFINED.
C
 1001 FORMAT (A6)
 2001 FORMAT (//41X 35HJOINT DATA USED IN SUBROUTINE FINEL)
 2002 FORMAT (//35X 47HJOINT DATA USED IN SUBROUTINE FINEL (CONTINUED))
 2003 FORMAT ( /16X 18HDEGREES OF FREEDOM
     *          18X 28HGLOBAL CARTESIAN COORDINATES
     *          12X 22HEULER ANGLES (DEGREES)
     *         /14X 11HTRANSLATION 8X 8HROTATION
     *         / 2X5HJOINT 6X1HU 5X1HV 5X1HW 5X1HP 5X1HQ 5X1HR
     *          11X1HX 11X1HY 11X1HZ 14X1HX 10X1HY 10X1HZ /)
 2004 FORMAT (1X I5, 3X 6I6, 3X 3F12.4, 4X 3F11.4)
C
      IF (NUTMX .GT. 0) REWIND NUTMX
      IF (NUTKX .GT. 0) REWIND NUTKX
      IF (NUTE  .GT. 0) REWIND NUTE
      IF (NUTLT .GT. 0) REWIND NUTLT
      IF (NUTST .GT. 0) REWIND NUTST
C
C  DETERMINE SIZE OF FINAL MASS-STIFFNESS MATRIX FROM THE MAXIMUM DOF
C  NUMBER IN JDOF.
      NDOF = JDOF(1,1)
      DO 35 I=1,NJ
      DO 35 J=1,6
      IF (JDOF(I,J) .GT. NDOF) NDOF=JDOF(I,J)
   35 CONTINUE
C
C  PRINT JOINT DOF, XYZ COORDINATES, EULER ANGLES.
      CALL PAGEHD
      WRITE (NOT,2001)
      WRITE (NOT,2003)
      NLINE = 0
      DO 40 IJ=1,NJ
      NLINE = NLINE+1
      IF (NLINE .LE. 42) GO TO 40
      CALL PAGEHD
      WRITE (NOT,2002)
      WRITE (NOT,2003)
      NLINE = 1
   40 WRITE (NOT,2004) IJ, (JDOF(IJ,J), J=1,6), (XYZ(IJ,J), J=1,3),
     *                     (EUL(IJ,J), J=1,3)
C
C  READ FINITE ELEMENT TYPE.
   50 READ (NUTEL,1001) NAMEL
      IF (NAMEL .EQ. 6HRETURN) GO TO 500
```

```
      IF (NAMEL .EQ. 6HAXIAL ) GO TO 110
      IF (NAMEL .EQ. 6HBAR   ) GO TO 140
      IF (NAMEL .EQ. 6HTRNGL ) GO TO 150
      IF (NAMEL .EQ. 6HFLUID ) GO TO 151
      IF (NAMEL .EQ. 6HQUAD  ) GO TO 160
      IF (NAMEL .EQ. 6HRECTSP) GO TO 162
      IF (NAMEL .EQ. 6HGRAVTY) GO TO 171
                                                                      NERROR=1
                                                                          GO TO 999
C  BAR FINITE ELEMENT (AXIAL ONLY).
  110 CALL AXIAL  (XYZ,JDOF,EUL,NUTEL,NJ,
     *                NUTMX,NUTKX,NUTLT,NUTST,
     *                W1,W2,W3,KRX,KRJ,KRE,KW)
      GO TO 50
C  BAR FINITE ELEMENT (COMBINED AXIAL, TORSION, BENDING).
  140 CALL BAR    (XYZ,JDOF,EUL,NUTEL,NJ,
     *                NUTMX,NUTKX,NUTB,NUTLT,NUTST,
     *                W1,W2,W3,KRX,KRJ,KRE,KW)
      GO TO 50
C  TRIANGULAR PLATE ELEMENT.
  150 CALL TRNGL  (XYZ,JDOF,EUL,NUTEL,NJ,
     *                NUTMX,NUTKX,NUTB,NUTLT,NUTST,
     *                W1,W2,W3,KRX,KRJ,KRE,KW)
      GO TO 50
C  FLUID ELEMENT.
  151 CALL FLUID  (XYZ,JDOF,EUL,NUTEL,NJ,
     *                NUTMX,NUTKX,      NUTLT,NUTST,
     *                W1,W2,W3,KRX,KRJ,KRE,KW)
      GO TO 50
C  QUADRILATERAL PLATE ELEMENT.
  160 CALL QUAD   (XYZ,JDOF,EUL,NUTEL,NJ,
     *                NUTMX,NUTKX,NUTB,NUTLT,NUTST,
     *                W1,W2,W3,KRX,KRJ,KRE,KW)
      GO TO 50
C  RECTANGULAR SHEAR PANEL.
  162 CALL RECTSP (XYZ,JDOF,EUL,NUTEL,NJ,
     *                NUTMX,NUTKX,NUTLT,NUTST,
     *                W1,W2,W3,KRX,KRJ,KRE,KW)
      GO TO 50
C  GRAVITY ELEMENT.
  171 CALL GRAVTY (XYZ,JDOF,EUL,NUTEL,NJ,
     *                      NUTKX,
     *                W1,W2,W3,KRX,KRJ,KRE,KW)
      GO TO 50
C
C  TERMINATE FINITE ELEMENT DATA ON STORAGE DISKS.
  500 IF (NUTMX .GT. 0) WRITE (NUTMX) IBLANK,(I1,I=1,30)
      IF (NUTKX .GT. 0) WRITE (NUTKX) IBLANK,(I1,I=1,30)
      IF (NUTB  .GT. 0) WRITE (NUTB)  IBLANK,(I1,I=1,30)
      IF (NUTLT .GT. 0) WRITE (NUTLT) IBLANK,(I1,I=1,30)
      IF (NUTST .GT. 0) WRITE (NUTST) IBLANK,(I1,I=1,30)
C
C  SUM FINITE ELEMENT MATRICES.
      IF (NUTM.GT.0) CALL YZERO (NUTM,NDOF,NDOF)
      IF (NUTK.GT.0) CALL YZERO (NUTK,NDOF,NDOF)
```

```
      IF (NUTMX .GT. 0) CALL YRVAD2 (NUTMX,NUTM,NDOF,W1,KW,V,LV,KV,
     *                               NUT1,NUT2,NUT3)
      IF (NUTKX .GT. 0) CALL YRVAD2 (NUTKX,NUTK,NDOF,W1,KW,V,LV,KV,
     *                               NUT1,NUT2,NUT3)
      RETURN
C
  999 CALL ZZBOMB (6HFINEL ,NERROR)
      END
```

```
      SUBROUTINE FLUID (XYZ,JDOF,EUL,NUTEL,NJ,
     *     NUTMX,NUTKX,        NUTLT,NUTST,
     *     W, T, S, KX, KJ, KE, KW)
      DIMENSION XYZ(KX,1),JDOF(KJ,1), EUL(KE,1), W(KW,1),
     *    T(KW,1), S(KW,1)
      DIMENSION CJ(3,8),EJ(3,8),IV1(24),IVTET(12),JM(4,16),VL(10),
     *          DV(12),DIST(12,12),TV(24)
      DATA NRW,NRST/24,1/, IBLNK/6H      /,I1ST /0/
      DATA NIT,NOT/ 5,6 /
      DATA NAMEL / 6HFLUID  /
      DATA KCJ / 3 /, KJM / 4 /
      DATA KDIST / 12 / , IFBAD / 1 /
      DATA JM/1,2,3,4, 3,6,4,2, 2,6,4,5, 3,5,1,2,
     *        1,3,6,5, 1,6,4,5, 2,7,4,5, 1,2,4,5,
     *        4,7,8,5, 5,2,7,6, 4,2,3,7, 1,3,8,6,
     *        1,6,8,5, 1,3,4,8, 1,2,3,6, 8,3,7,6  /
C
C  SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
C     MASS MATRICES AND IVECS (ON NUTMX),
C     STIFFNESS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
C     AND IVECS (ON NUTKX),
C     PRESSURE TRANSFORMATION MATRICES AND IVECS (ON NUTST),
C  FOR FLUID ELEMENTS.
C  ELEMENT SHAPE MAY BE TETRAHEDRON, PENTAHEDRON, OR HEXAHEDRON.
C  MASS, STIFFNESS MATRICES ARE IN GLOBAL COORDINATE DIRECTIONS.
C  GLOBAL COORDINATE ORDER IS
C     (U,V,W) JOINT 1, THEN JOINT 2,3,4,(5,6,7,8).
C  WHERE U,V,W ARE TRANSLATIONS.
C  IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
C     IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C     IVEC(3)=0   OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINS
C                 ELEMENT DOF 3 TO ZERO MOTION.
C  PRESSURE TRANSFORMATION MATRICES RELATE CHANGE IN PRESSURE (DUE TO
C  COMPRESSIBILITY) TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C  PRESSURE CHANGE WITHIN THE FLUID ELEMENT IS CONSTANT. STATIC PRESSURE
C  DUE TO GRAVITY AND FLUID HEIGHT IS NOT INCLUDED.
C  DATA ARRANGEMENT ON NUTMX, NUTKX, NUTST FOR EACH FINITE ELEMENT IS
C  (W=M,K,ST)
C     WRITE (NUTWX) NAMEW,NEL,NR,NC,NAMEL,(IBLNK,I=1,5),
C                  ((W(I,J),I=1,NR),J=1,NC),(IVEC(I),I=1,NC)
C  CALLS FORMA SUBROUTINES TEGEOM,VCROSS,VDOT  ,ZZBOMB.
C  DEVELOPED BY C S BODLEY.  FEBRUARY 1974.
C  LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C  INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = NIT, DATA IS
C  READ FROM CARDS.
C     NAMEM,NAMEK,NAMELT,NAMEST                    FORMAT (4(A6,4X)
C     RC,BKM                                       FORMAT (2(5X,E10))
C  20 NEL,J1,J2,J3,J4,J5,J6,J7,J8                  FORMAT (9I5)
C     IF (J1 .EQ. 0) RETURN
C     GO TO 20
C
C  DEFINITION OF INPUT VARIABLES.
C  NAMEM  = TYPE OF MASS MATRIX WANTED.
C         = M1, LUMPED MASS MATRIX.
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C          = M2, QUASI-IRROTATIONAL CONSISTENT MASS MATRIX.
C          = M3, IRROTATIONAL MASS MATRIX.
C            = 6H        OR 6HNOMASS, NO MASS MATRIX CALCULATED.
C  NAMEK   = TYPE OF STIFFNESS MATRIX WANTED.
C            = K1, LINEAR DISPLACEMENT ASSUMED.
C            = 6H        OR 6HNOSTIF, NO STIFFNESS MATRIX CALCULATED.
C  NAMELT  = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES. (NOT YET).
C  NAMEST  = IDENTIFICATION NAME FOR PRESSURE TRANSFORMATION MATRICES.
C            = 6H        OR 6HNOSTRS, NO PRESSURE TRANSFORMATIONS CALCULATED.
C  RO      = MASS DENSITY.
C  BKM     = BULK MODULUS.
C  NEL     = FINITE ELEMENT NUMBER. FOR REFERENCE ONLY, NOT USED IN
C            CALCULATIONS. WRITTEN ON NUTMX, ETC.
C  J1      = JOINT NUMBER AT ELEMENT VERTEX 1.
C  J2      = JOINT NUMBER AT ELEMENT VERTEX 2.
C  J3      = JOINT NUMBER AT ELEMENT VERTEX 3.
C  J4      = JOINT NUMBER AT ELEMENT VERTEX 4.
C            FOR A TETRAHEDRON. FACE 1,2,3 MUST BE NUMBERED CLOCKWISE AS
C            VIEWED FROM OUTSIDE THE ELEMENT.
C  J5      = JOINT NUMBER AT ELEMENT VERTEX 5. (USED FOR PENTAHEDRON AND
C            HEXAHEDRON).
C  J6      = JOINT NUMBER AT ELEMENT VERTEX 6. (USED FOR PENTAHEDRON AND
C            HEXAHEDRON).
C            FOR A PENTAHEDRON, FACE 1,2,3 MUST BE NUMBERED CLOCKWISE AS
C            VIEWED FROM OUTSIDE THE ELEMENT. FACE 4,5,6 IS NUMBERED IN
C            THE SAME ORDER AS FACE 1,2,3. A LINE JOINING JOINTS 1 AND 4
C            MUST FORM AN EDGE OF THE PENTAHEDRON.
C  J7      = JOINT NUMBER AT ELEMENT VERTEX 7. (USED FOR HEXAHEDRON).
C  J8      = JOINT NUMBER AT ELEMENT VERTEX 8. (USED FOR HEXAHEDRON).
C            FOR A HEXAHEDRON, FACE 1,2,3,4 MUST BE NUMBERED CLOCKWISE
C            AS VIEWED FROM OUTSIDE THE ELEMENT. FACE 5,6,7,8 IS NUMBERED
C            IN THE SAME ORDER AS FACE 1,2,3,4. A LINE JOINING JOINTS 1
C            AND 5 MUST FORM AN EDGE OF THE HEXAHEDRON.
C
C  EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C     I = INTEGER DATA, RIGHT ADJUSTED.
C     E = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.
C     X = CARD COLUMNS SKIPPED.
C
C     SUBROUTINE ARGUMENTS (ALL INPUT)
C  XYZ     = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND
C            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C            X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
C  JDOF    = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C            TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C            ROTATION DOFS. SIZE(NJ,6).
C  EUL     = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C            GLOBAL X,Y,Z PERMUTATION. SIZE(NJ,3).
C  NUTEL   = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
C            THIS SUBROUTINE. IF NUTEL = NIT, DATA IS READ FROM CARDS.
C  NJ      = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C  NUTMX   = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C            MASS MATRICES AND IVECS ARE OUTPUT.
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C           NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C           USES FORTRAN READ, WRITE.
C  NUTKX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C           STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C           MATRICES) AND IVECS ARE OUTPUT.
C           NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C           USES FORTRAN READ, WRITE.
C  NUTLT  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOAD
C           TRANSFORMATION MATRICES AND IVECS ARE OUTPUT. (NOT YET).
C  NUTST  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C           PRESSURE TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C           NUTST MAY BE ZERO IF PRESSURE TRANSFORMATIONS ARE NOT FORMED.
C           USES FORTRAN READ, WRITE.
C  W      = MATRIX WORK SPACE. MIN SIZE(24,24).
C  T      = MATRIX WORK SPACE. MIN SIZE(24,24).
C  S      = MATRIX WORK SPACE. MIN SIZE(24,24).
C  KX     = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C  KJ     = ROW DIMENSION OF JDOF IN CALLING PROGRAM.
C  KE     = ROW DIMENSION OF EUL IN CALLING PROGRAM.
C  KW     = ROW DIMENSION OF W, T, AND S IN CALLING PROGRAM. MIN=24.
C
C     NERROR  EXPLANATION
C  1 = INCORRECT TETRAHEDRON GEOMETRY.
C  2 = INPUT JOINT NUMBER EXCEEDS MAXIMUM ALLOWABLE NUMBER OF JOINTS.
C  3 = NUTMX NOT POSITIVE.
C  4 = NUTKX NOT POSITUVE.
C  5 = NUTST NOT POSITIVE.
C
 1001 FORMAT (5(A6,4X))
 1002 FORMAT (3(5X,E10.0))
 1003 FORMAT (9I5)
 2001 FORMAT (//25X 38HINPUT DATA FOR FLUID (TETRA, PENTA, OR
     *   21H HEXAHEDRON) ELEMENTS)
 2002 FORMAT (//20X 38HINPUT DATA FOR FLUID (TETRA, PENTA, OR
     *   33H HEXAHEDRON) ELEMENTS (CONTINUED))
 2003 FORMAT (/12X7HMASS = A6,13X7HSTIF = A6,6X13HLOAD TRANS = A6,
     *            3X15HSTRESS TRANS = A6, 3X
     *         / 15X,4HRO = E10.3, 13X7HBULKM = E10.3,
     * // 9X7HELEMENT 6  HJOINT 1 6X7HJOINT 2 6X7HJOINT 3 6X7HJOINT 4
     *                  6X7HJOINT 5 6X7HJOINT 6 6X7HJOINT 7 6X7HJOINT 8
     *         / 9X6HNUMBER)
 2004 FORMAT (3X,9(8X,I5))
 3001 FORMAT (51H * * * * * UNCONVENTIONAL JOINT NUMBERING * * * * * , /
     *        9I5)
C
C
      IF (I1ST .EQ. 1) GO TO 3
      I1ST = 1
      DO 4 I=1,4
      I1 = 3*I - 2
      DO 4 J=1,4
      J1 = 3*J - 2
    4 CALL UNITY (DIST(I1,J1),3,KDIST)
C
    3 NLINE = 0
```

```
      CALL PAGEHD
      WRITE (NOT,2001)
      READ (NUTEL,1001) NAMEM,NAMEK,NAMELT,NAMEST
      READ (NUTEL,1002)  RO, BKM
      WRITE (NOT,2003) NAMEM,NAMEK,NAMELT,NAMEST,
     *                RO, BKM
      IF (NAMEM .NE. 6HM3     ) GO TO 20
      DO 2 I=1,12
    2 DIST(I,I) = 2.
C
   20 READ (NUTEL,1003) NEL,J1,J2,J3,J4,J5,J6,J7,J8
                                                                 NERROR=1
      IF (J1.LE.0 .AND. IFBAD.EQ.-1) GO TO 999
      IF (J1 .LE. 0) RETURN
      NLINE = NLINE + 1
      IF (NLINE .LE. 42) GO TO 30
      CALL PAGEHD
      WRITE (NOT,2002)
      WRITE (NOT,2003) NAMEM,NAMEK,NAMELT,NAMEST,
     *         RO,  BKM
      NLINE = 0
   30 WRITE (NOT,2004) NEL,J1,J2,J3,J4,J5,J6,J7,J8
                                                                 NERROR=2
      IF (J1.GT.NJ .OR. J2.GT.NJ .OR. J3.GT.NJ .OR. J4.GT.NJ) GO TO 999
      IF (J5.GT.NJ .OR. J6.GT.NJ .OR. J7.GT.NJ .OR. J8.GT.NJ) GO TO 999
C
C  FORM FINITE ELEMENT COORDINATE LOCATIONS,EULER ANGLES, REVADD IVEC.
C
      LR = 10
      NJN = 8
      IF (J7 .NE. 0) GO TO 38
      LR = 6
      NJN = 6
      IF (J5 .NE. 0) GO TO 38
      LR = 1
      NJN = 4
C
   38 NCOL = 3*NJN
      DO 5 I=1,NCOL
      DO 5 J=1,NCOL
      W(I,J) = 0.
      S(I,J) = 0.
    5 T(I,J) = 0.
C
      DO 40 I=1,3
      CJ(I,1) = XYZ(J1,I)
      CJ(I,2) = XYZ(J2,I)
      CJ(I,3) = XYZ(J3,I)
      CJ(I,4) = XYZ(J4,I)
      EJ(I,1) = EUL(J1,I)
      EJ(I,2) = EUL(J2,I)
      EJ(I,3) = EUL(J3,I)
      EJ(I,4) = EUL(J4,I)
      IV1(I  ) = JDOF(J1,I)
      IV1(I+3) = JDOF(J2,I)
```

```
      IV1(I+6) = JDOF(J3,I)
   40 IV1(I+9) = JDOF(J4,I)
      IF (LR .EQ. 1) GO TO 50
C
      DO 42 I=1,3
      CJ(I,5) = XYZ(J5,I)
      CJ(I,6) = XYZ(J6,I)
      EJ(I,5) = EUL(J5,I)
      EJ(I,6) = EUL(J6,I)
      IV1(I+12) = JDOF(J5,I)
   42 IV1(I+15) = JDOF(J6,I)
      IF (LR .EQ. 6) GO TO 50
C
      DO 44 I=1,3
      CJ(I,7) = XYZ(J7,I)
      CJ(I,8) = XYZ(J8,I)
      EJ(I,7) = EUL(J7,I)
      EJ(I,8) = EUL(J8,I)
      IV1(I+18) = JDOF(J7,I)
   44 IV1(I+21) = JDOF(J8,I)
C
   50 DO 52 L=1,LR
      LA = L
      IF (LR.EQ.10) LA=L+6
      DO 53 I=1,4
      JNO = JM(I,LA)
      L1 = 3*I - 2
      IVTET(L1  ) = 3*JNO - 2
      IVTET(L1+1) = 3*JNO - 1
   53 IVTET(L1+2) = 3*JNO
C
      CALL TEGEOM (CJ,JM(1,LA   ),VL(L),DV,       KCJ,IFBAD)
      IF (IFBAD.NE.0) GO TO 51
      WRITE (NOT,3001) NEL,J1,J2,J3,J4,J5,J6,J7,J8
      IFBAD = -1
   51 SM = RO*VL(L)/16.0
      IF (NAMEM .EQ. 6HM3     ) SM=RO*VL(L)/20.0
      IF (LR .GT. 1)  SM = SM/2.
      CALL REVADD (1.,DV,L,IVTET,T,1,12,LR,NCOL,1,KW)
   52 CALL REVADD (SM,DIST,IVTET,IVTET,W,12,12,NCOL,NCOL,KDIST,KW)
C
      IF (NAMEM .NE. 6HM1     ) GO TO 220
      DO 210 I=1,NCOL
      SAVE = 0.0
      DO 215 J=1,NCOL
      SAVE = SAVE + W(I,J)
  215 W(I,J) = 0.0
  210 W(I,I) = SAVE
C
  220 IF (LR .EQ. 1) GO TO 60
      DO 55 I=2,LR
      VL(1) = VL(1) + VL(I)
      DO 55 J=1,NCOL
   55 T(1,J) = T(1,J) + T(I,J)
      VL(1) = VL(1)/2.
```

```
      DO 56 J=1,NCOL
   56 T(1,J) = T(1,J)/2.
C
   60 DO 61 J=1,NCOL
   61 TV(J) = T(1,J)
      DO 65 J=1,NJN
      J1 = 3*J - 2
   65 CALL EULER (EJ(1,J),S(J1,J1),KW)
      IF (NAMEST .EQ. 6H       .OR. NAMEST .EQ. 6HNOSTRS) GO TO 90
      CALL PRESS (CJ,T,NJN,NCOL,KCJ,KW)
      CALL MULTA (T,S,NJN,NCOL,NCOL,KW,KW)
   90 CALL BTABA (W,S,NCOL,NCOL,KW,KW)
      CALL MULTA (TV,S,1,NCOL,NCOL,1,KW)
      BOV = EKM/VL(1)
      DO 70 I=1,NCOL
      DO 70 J=I,NCOL
      S(I,J) = BOV*TV(I)*TV(J)
   70 S(J,I) = S(I,J)
C
      IF (NAMEM .EQ. 6H       .OR. NAMEM .EQ. 6HNOMASS) GO TO 110
                                                                 NERROR=3
      IF (NUTMX .LE. 0) GO TO 999
      WRITE (NUTMX) NAMEM,NEL,NCOL,NCOL,NAMEL,(IBLNK,I=1,5),
     *    ((W(I,J),I=1,NCOL),J=1,NCOL), (IV1(I),I=1,NCOL)
C
  110 IF (NAMEK .EQ. 6H       .OR. NAMEK .EQ. 6HNOSTIF) GO TO 120
                                                                 NERROR=4
      IF (NUTKX .LE. 0) GO TO 999
      WRITE (NUTKX) NAMEK,NEL,NCOL,NCOL,NAMEL,(IBLNK,I=1,5),
     *    ((S(I,J),I=1,NCOL),J=1,NCOL), (IV1(I),I=1,NCOL)
C
  120 IF (NAMEST .EQ. 6H       .OR. NAMEST .EQ. 6HNOSTRS) GO TO 20
                                                                 NERROR=5
      IF (NUTST .LE. 0) GO TO 999
      NJNP1 = NJN + 1
      CALL MULT  (T,S,T(NJNP1,1),NJN,NCOL,NCOL,KW,KW)
      CALL MULTA  (T,W,NJN,NCOL,NCOL,KW,KW)
      NRST = 2*NJN
      WRITE (NUTST) NAMEST,NEL,NRST,NCOL,NAMEL,VL(1),(IBLNK,I=1,4),
     *   ((T(I,J),I=1,NRST),J=1,NCOL), (IV1(I),I=1,NCOL)
      GO TO 20
C
  999 CALL ZZBOMB (6HFLUID ,NERROR)
      END
```

```
      SUBROUTINE GRAVTY (XYZ,JDOF,EUL,NUTEL,NJ,
     *           NUTKX,
     *     W, T, S, KX, KJ, KE, KW)
      DIMENSION XYZ(KX,1),JDOF(KJ,1), EUL(KE,1), W(KW,1),
     *     (KW,1), S(KW,1)
      DIMENSION CJ(3,4),EJ(3,4),IV1(12),IVTRI(9),JM(3,4),GV(3),EV(3)
      DATA IBLNK/6H      /
      DATA NIT,NOT/ 5,6 /
      DATA NAMEL / 6HGRAVTY /
      DATA KCJM / 3 /
      DATA  JM / 1,2,3, 1,3,4, 1,2,4, 4,2,3 /
C
C  SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
C     STIFFNESS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
C     AND IVECS (ON NUTKX),
C  FOR GRAVITY ELEMENTS.
C  STIFFNESS MATRICES AR+ 9- GL021- 300R49-1T  4IR  090-S8
C  GLOBAL COORDINATE ORDER IS
C     (U,V,W) JOINT 1, THEN JOINT 2,3,(4).
C  WHERE U,V,W ARE TRANSLATIONS.
C  IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
C     IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C     IVEC(3)=0   OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINS
C                 ELEMENT DOF 3 TO ZERO MOTION.
C  DATA ARRANGEMENT ON NUTKX FOR EACH FINITE ELEMENT IS
C  (W=K)
C     WRITE (NUTWX) NAMEW,NEL,NR,NC,NAMEL,(IBLNK,I=1,5),
C                    ((W(I,J),I=1,NR),J=1,NC),(IVEC(I),I=1,NC)
C  CALLS FORMA SUBROUTINES KGRAV ,MULTA ,MULTB ,VCROSS,ZZBOMB.
C  DEVELOPED BY C S BODLEY.  FEBRUARY 1974.
C  LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C  ***********************************************************************
C  INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = NIT, DATA IS
C  READ FROM CARDS.
C     NAMEM,NAMEK                                 FORMAT (2(A6,4X)
C     RO                                          FORMAT (5X,E10)
C     (GV(I),I=1,3)                               FORMAT (3(5X,E10))
C  20 NEL,J1,J2,J3,J4                             FORMAT (5I5)
C     IF (J1 .EQ. 0) RETURN
C     GO TO 20
C
C  DEFINITION OF INPUT VARIABLES.
C  NAMEM  = TYPE OF MASS MATRIX WANTED.
C           = 6H       OR 6HNOMASS, NO MASS MATRIX CALCULATED.
C  NAMEK  = TYPE OF STIFFNESS MATRIX WANTED.
C           = K1, LINEAR DISPLACEMENT ASSUMED.
C           = 6H       OR 6HNOSTIF, NO STIFFNESS MATRIX CALCULATED.
C  RO     = MASS DENSITY.
C  GV     = GRAVITY VECTOR.
C  NEL    = FINITE ELEMENT NUMBER. FOR REFERENCE ONLY, NOT USED IN
C           CALCULATIONS. WRITTEN ON NUTKX.
C  J1     = JOINT NUMBER AT ELEMENT VERTEX 1.
C  J2     = JOINT NUMBER AT ELEMENT VERTEX 2.
C  J3     = JOINT NUMBER AT ELEMENT VERTEX 3.
```

```
C  J4     = JOINT NUMBER AT ELEMENT VERTEX 4. (USED FOR QUADRILATERAL).
C  THE ELEMENT MUST BE NUMBERED CLOCKWISE AS VIEWED FROM THE FLUID SIDE
C  OF THE ELEMENT.
C
C  EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C     I = INTEGER DATA, RIGHT ADJUSTED.
C     E = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.
C     X = CARD COLUMNS SKIPPED.
C  ************************************************************************
C
C     SUBROUTINE ARGUMENTS (ALL INPUT)
C  XYZ    = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND
C           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C           X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
C  JDOF   = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C           TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C           ROTATION DOFS. SIZE(NJ,6).
C  EUL    = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C           GLOBAL X,Y,Z PERMUTATION. SIZE(NJ,3).
C  NUTEL  = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
C           THIS SUBROUTINE. IF NUTEL = NIT, DATA IS READ FROM CARDS.
C  NJ     = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C  NUTKX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C           STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C           MATRICES) AND IVECS ARE OUTPUT.
C           NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C           USES FORTRAN READ, WRITE.
C  W      = MATRIX WORK SPACE. MIN SIZE(12,12).
C  T      = MATRIX WORK SPACE. MIN SIZE(12,12).
C  S      = MATRIX WORK SPACE. MIN SIZE(12,12).
C  KX     = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C  KJ     = ROW DIMENSION OF JDOF IN CALLING PROGRAM.
C  KE     = ROW DIMENSION OF EUL IN CALLING PROGRAM.
C  KW     = ROW DIMENSION OF W, T, AND S IN CALLING PROGRAM. MIN=12.
C
C     NERROR  EXPLANATION
C  1 = INPUT JOINT NUMBER EXCEEDS MAXIMUM ALLOWABLE NUMBER OF JOINTS.
C  2 = NUTKX NOT POSITIVE.
C
 1001 FORMAT (5(A6,4X))
 1002 FORMAT (3(5X,E10.0))
 1003 FORMAT (5I5)
 2001 FORMAT (//25X  45HINPUT DATA FOR GRAVITY STIFFNESS (TRIANGLE OR
     *               24H QUADRILATERAL) ELEMENTS)
 2002 FORMAT (//20X  45HINPUT DATA FOR GRAVITY STIFFNESS (TRIANGLE OR
     *               36H QUADRILATERAL) ELEMENTS (CONTINUED))
 2003 FORMAT (/12X7HMASS = A6,13X7HSTIF = A6,6X
     *        / 15X,4HRO = E10.3, 13X5HGVX = E10.3, 13X5HGVY = E10.3,
     *                           13X5HGVZ = E10.3,
     * //15X7HELEMENT 13X7HJOINT 1 13X7HJOINT 2 13X7HJOINT 3
     *                13X7HJOINT 4
     *        /15X6HNUMBER)
 2004 FORMAT (18X,9(I5,15X))
```

```
C
C
      NLINE = 0
      CALL PAGEHD
      WRITE (NOT,2001)
      READ (NUTEL,1001) NAMEM,NAMEK
      READ (NUTEL,1002)  RO
      READ (NUTEL,1002)  (GV(I),I=1,3)
      WRITE (NOT,2003) NAMEM,NAMEK,
     *               RO,  (GV(I),I=1,3)
C
   20 READ (NUTEL,1003) NEL,J1,J2,J3,J4
      IF (J1 .LE. 0) RETURN
      NLINE = NLINE + 1
      IF (NLINE .LE. 42) GO TO 30
      CALL PAGEHD
      WRITE (NOT,2002)
      WRITE (NOT,2003) NAMEM,NAMEK,
     *        RO,   (GV(I),I=1,3)
      NLINE = 0
   30 WRITE (NOT,2004) NEL,J1,J2,J3,J4
                                                                 NERROR=1
      IF (J1.GT.NJ .OR. J2.GT.NJ .OR. J3.GT.NJ .OR. J4.GT.NJ) GO TO 999
C
C  FORM FINITE ELEMENT COORDINATE LOCATIONS,EULER ANGLES, REVADD IVEC.
C
      LR = 4
      NJN = 4
      IF (J4 .NE. 0) GO TO 38
      LR = 1
      NJN = 3
   38 NCOL = 3*NJN
      DO 5 I=1,NCOL
      DO 5 J=1,NCOL
      W(I,J) = 0.
      S(I,J) = 0.
    5 T(I,J) = 0.
C
      DO 40 I=1,3
      CJ(I,1) = XYZ(J1,I)
      CJ(I,2) = XYZ(J2,I)
      CJ(I,3) = XYZ(J3,I)
      EJ(I,1) = EUL(J1,I)
      EJ(I,2) = EUL(J2,I)
      EJ(I,3) = EUL(J3,I)
      IV1(I   ) = JDOF(J1,I)
      IV1(I+3) = JDOF(J2,I)
   40 IV1(I+6) = JDOF(J3,I)
      IF (LR .EQ. 1) GO TO 50
C
      DO 42 I=1,3
      CJ(I,4) = XYZ(J4,I)
      EJ(I,4) = EUL(J4,I)
   42 IV1(I+9) = JDOF(J4,I)
C
```

```
   50 G = SQRT(GV(1)**2 + GV(2)**2 + GV(3)**2)
      DO 51 I=1,3
   51 EV(I) = -GV(I)/G
       DO 52 L=1,LR
      CALL KGRAV  (CJ,JM(1,L),EV,A,W,KW,KCJM)
C
      DO 53 I=1,3
      JNO = JM(I,L)
      L1 = 3*I - 2
      IVTRI(L1  ) = 3*JNO - 2
      IVTRI(L1+1) = 3*JNO - 1
   53 IVTRI(L1+2) = 3*JNO
      SS = RO*G*A/24.
      IF (LR .GT. 1) SS = SS/2.
   52 CALL REVADD (SS,W,IVTRI,IVTRI,S,9,9,NCOL,NCOL,KW,KW)
C
      DO 65 J=1,NJN
      J1 = 3*J - 2
   65 CALL EULEP  (FJ(1,J),T(J1,J1),KW)
      CALL ETABA  (S,T,NCOL,NCOL,KW,KW)
C
      IF (NAMEK .EQ. 6H       .OR. NAMEK .EQ. 6HNOSTIF) GO TO  20
                                                         NERROR=2
      IF (NUTKY .LE. 0) GO TO 999
      WRITE (NUTKX) NAMEK,NEL,NCOL,NCOL,NAMEL,(IBLNK,I=1,5),
     *    ((S(I,J),I=1,NCOL),J=1,NCOL), (IV1(I),I=1,NCOL)
C
      GO TO 20
C
  999 CALL ZZBOMB (6HGRAVTY,NERROR)
      END
```

```
      SUBROUTINE K1A1   (A1,A2,RL,E,Z,TS,KZ,KTS)
      DIMENSION Z(KZ,1), TS(KTS,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     STIFFNESS MATRIX,
C     STRESS TRANSFORMATION MATRIX,
C  FOR AN AXIAL ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  ROD MAY BE LINEARLY TAPERED OR UNIFORM.
C  CONSTANT FORCE ASSUMED.
C  STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C  STRESS TRANSFORMATION MATRIX RELATES STRESS AT ROD ENDS IN LOCAL
C  COORDINATE SYSTEM TO DEFLECTIONS IN LOCAL COORDINATE SYSTEM.
C  ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C     SIGMA-X1, SIGMA-X2
C  WHERE SIGMA IS NORMAL STRESS.
C  SX1(-), SX2(+) IS TENSION. SX1(+), SX2(-) IS COMPRESSION.
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C  WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C  LOCAL COORDINATE ORDER IS
C     DX1,DX2
C  WHERE DX IS TRANSLATION.
C  DEVELOPED BY  RL WOHLEN.  SEPTEMBER 1972.
C  LAST REVISION BY RL WOHLEN.  SEPTEMBER 1973.
C
C     SUBROUTINE ARGUMENTS
C  A1  = INPUT  CROSS-SECTION AREA AT ROD END 1.
C  A2  = INPUT  CROSS-SECTION AREA AT ROD END 2.
C  RL  = INPUT  ROD LENGTH.
C  E   = INPUT  YOUNGS MODULUS OF ELASTICITY.
C  Z   = OUTPUT STIFFNESS MATRIX. SIZE(2,2).
C  TS  = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(2,2).
C  KZ  = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C  KTS = INPUT  ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=2.
C
      S = A1*E/RL
      R = A2/A1
      IF (ABS(R-1.) .GT. .01) S = (A2-A1)*E / (RL*ALOG(R))
C  STIFFNESS MATRIX.
      Z(1,1) = S
      Z(1,2) =-S
      Z(2,1) =-S
      Z(2,2) = S
C
C  STRESS TRANSFORMATION MATRIX.
      TS(1,1) = Z(1,1)/A1
      TS(1,2) = Z(1,2)/A1
      TS(2,1) = Z(2,1)/A2
      TS(2,2) = Z(2,2)/A2
C
      RETURN
      END
```

```
      SUBROUTINE K1B1   (BI1,BI2,C1,C2,A1,A2,SF,RL,E,G,Z,TS,KZ,KTS)
      DIMENSION Z(KZ,1), TS(KTS,1)
      DATA EPS/1.E-15/
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     STIFFNESS MATRIX,
C     STRESS TRANSFORMATION MATRIX,
C  FOR A BENDING (PLUS SHEAR) BEAM ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  BEAM MAY BE LINEARLY TAPERED OR UNIFORM.
C  UNIFORM SHEAR AND LINEAR BENDING MOMENT VARIATION IS ASSUMED.
C  SHEAR STIFFNESS USES SF*A1*G AND SF*A2*G. IF ANY OF THESE VARIABLES
C  ARE ZERO, THERE IS NO SHEAR DEFORMATION IN BENDING.
C  STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C  STRESS TRANSFORMATION MATRIX RELATES STRESS AT BEAM ENDS IN LOCAL
C  COORDINATE SYSTEM TO DEFLECTIONS IN LOCAL COORDINATE SYSTEM.
C  ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C     TAU-X1,TAU-X2,SIGMA-X1,SIGMA-X2
C  WHERE SIGMA IS NORMAL STRESS (MC/I) AND TAU IS SHEAR STRESS (P/A).
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE BEAM TO LIE IN THE X-Z PLANE
C  WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C  LOCAL COORDINATE ORDER IS
C     DZ1,DZ2,TY1,TY2
C  WHERE DZ IS TRANSLATION AND TY IS ROTATION.
C  DEVELOPED BY  RL WOHLEN.  FEBRUARY 1973.
C  LAST REVISION BY  RL WOHLEN.  APRIL 1976.
C
C     SUBROUTINE ARGUMENTS
C  BI1 = INPUT  CROSS-SECTION AREA MOMENT OF INERTIA AT BEAM END 1.
C  BI2 = INPUT  SAME AS BI1 AT BEAM END 2.
C  C1  = INPUT  DISTANCE FROM BENDING NEUTRAL AXIS TO OUTER FIBER
C               AT BEAM END 1.
C  C2  = INPUT  SAME AS C1 AT BEAM END 2.
C  A1  = INPUT  CROSS-SECTION AREA AT BEAM END 1. CAN BE ZERO FOR NO
C               SHEAR DEFORMATION IN BENDING. SHEAR STRESS IN STRESS
C               TRANSFORMATION WILL BE SET TO ZERO.
C  A2  = INPUT  SAME AS A1 AT BEAM END 2.
C  SF  = INPUT  SHAPE FACTOR (K) FOR SHEAR IN KAG.
C               USE SF=0.0 FOR NO SHEAR DEFORMATION IN BENDING.
C               SF=1.0 FOR A SOLID CIRCULAR CYLINDER.
C               SF=.5 FOR A THIN WALLED CIRCULAR CYLINDER.
C  RL  = INPUT  ROD LENGTH.
C  E   = INPUT  YOUNGS MODULUS OF ELASTICITY.
C  G   = INPUT  SHEAR MODULUS OF ELASTICITY. CAN BE ZERO FOR NO SHEAR
C               DEFORMATION IN BENDING.
C  Z   = OUTPUT STIFFNESS MATRIX. SIZE(4,4).
C  TS  = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(4,4).
C  KZ  = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=4.
C  KTS = INPUT  ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=4.
C
C  BENDING FLEXIBILITY.
      RBI = BI2/BI1
      RBIM1 = RBI-1.
      IF (ABS(RBIM1) .LT. .01) GO TO 15
      EBR = E*BI1*RBIM1
      RBILN = ALOG(RBI)
```

```
      F11 = (.5 - 1./RBIM1 + RBILN/RBIM1**2) * (RL**3) / EBR
      F12 = (1. - RBILN/RBIM1) * (RL**2) / EBR
      F22 = RL* RBILN / EBR
      GO TO 20
   15 F11 = RL**3 / (3.*E*BI1)
      F12 = RL**2 / (2.*E*BI1)
      F22 = RL/ (E*BI1)
C  SHEAR FLEXIBILITY.
   20 IF (SF.LT.EPS .OR. A1.LT.EPS .OR. A2.LT.EPS .OR. G.LT.EPS)GO TO 30
      RA = A2/A1
      IF (ABS(RA-1.) .LT. .01) GO TO 25
      F11 = F11 + RL * ALOG(RA) / (SF*G*(A2-A1))
      GO TO 30
   25 F11 = F11 + RL/(SF*A1*G)
C
C  BENDING + SHEAR STIFFNESS MATRIX.
   30 D = F11*F22 - F12**2
      Z(1,1) = F22/D
      Z(1,2) =-Z(1,1)
      Z(1,3) =-F12/D
      Z(1,4) = (-RL*F22 + F12)/D
      Z(2,2) = Z(1,1)
      Z(2,3) =-Z(1,3)
      Z(2,4) =-Z(1,4)
      Z(3,3) = F11/D
      Z(3,4) = (RL*F12 - F11)/D
      Z(4,4) = (F22*RL**2 - 2.*RL*F12 + F11)/D
C  SYMMETRIZE LOWER HALF.
      DO 40 J=1,4
      DO 40 I=J,4
   40 Z(I,J) = Z(J,I)
C
C  STRESS TRANSFORMATION MATRIX.
      DO 55 J=1,4
      TS(1,J) = 0.0
      TS(2,J) = 0.0
      IF (A1 .GT. 0.0) TS(1,J) = Z(1,J)/A1
      IF (A2 .GT. 0.0) TS(2,J) = Z(2,J)/A2
      TS(3,J) = Z(3,J)*C1/BI1
   55 TS(4,J) = Z(4,J)*C2/BI2
C
      RETURN
      END
```

```
      SUBROUTINE K1C1   (TJ1,TJ2,R1,R2,RL,G,Z,TS,KZ,KTS)
      DIMENSION Z(KZ,1), TS(KTS,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     STIFFNESS MATRIX,
C     STRESS TRANSFORMATION MATRIX,
C  FOR A TORSION ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  ROD MAY BE LINEARLY TAPERED OR UNIFORM.
C  CONSTANT TORQUE ASSUMED.
C  STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C  STRESS TRANSFORMATION MATRIX RELATES STRESS AT ROD ENDS IN LOCAL
C  COORDINATE SYSTEM TO ROTATIONS IN LOCAL COORDINATE SYSTEM.
C  ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C     TAU-X1,TAU-X2
C  WHERE TAU IS SHEAR STRESS.
C  STRESS IS + OR - AS RIGHT HAND AXIS BETWEEN END POINTS 1 AND 2.
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C  WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C  LOCAL COORDINATE ORDER IS
C     TX1,TX2
C  WHERE TX IS ROTATION.
C  DEVELOPED BY  RL WOHLEN.  FEBRUARY 1973.
C  LAST REVISION BY RL WOHLEN.  SEPTEMBER 1973.
C
C     SUBROUTINE ARGUMENTS
C  TJ1 = INPUT  CROSS-SECTION SAINT VENANTS TORSION CONSTANT (J) IN JG
C               AT ROD END 1. E.G., TJ1=.5*PI*R1**4 FOR A SOLID CIRCULAR
C               CYLINDER. TJ1=2.*PI*T*R1**3 FOR A THIN WALLED CIRCULAR
C               CYLINDER.
C  TJ2 = INPUT  CROSS-SECTION SAINT VENANTS TORSION CONSTANT (J) IN JG
C               AT ROD END 2.
C  R1  = INPUT  DISTANCE FROM TORSION AXIS TO OUTER FIBER AT ROD END 1.
C  R2  = INPUT  DISTANCE FROM TORSION AXIS TO OUTER FIBER AT ROD END 2.
C  RL  = INPUT  ROD LENGTH.
C  G   = INPUT  SHEAR MODULUS OF ELASTICITY.
C  Z   = OUTPUT STIFFNESS MATRIX. SIZE(2,2).
C  TS  = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(2,2).
C  KZ  = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C  KTS = INPUT  ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=2.
C
      S = TJ1*G/RL
      R = TJ2/TJ1
      IF (ABS(R-1.) .GT. .01) S = (TJ2-TJ1)*G / (RL*ALOG(R))
C  STIFFNESS MATRIX.
      Z(1,1) = S
      Z(1,2) =-S
      Z(2,1) =-S
      Z(2,2) = S
C
C  STRESS TRANSFORMATION MATRIX.
      TS(1,1) = Z(1,1)*R1/TJ1
      TS(1,2) = Z(1,2)*R1/TJ1
      TS(2,1) = Z(2,1)*R2/TJ2
      TS(2,2) = Z(2,2)*R2/TJ2
C
```

```
RETURN
END
```

```
      SUBROUTINE K2A1 (X2,X3,Y3,TH,E,ANU,Z,T,R,KZ,KT,KR)
      DIMENSION Z(KZ,1),T(KT,1),R(KR,1)
      DIMENSION XE(3),ET(3)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     STIFFNESS MATRIX,
C     STRESS TRANSFORMATION MATRIX,
C  FOR A MEMBRANE TRIANGLE PLATE ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  QUADRATIC DISPLACEMENT (LINEAR STRAIN) FIELD IS USED.
C  STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C  STRESS TRANSFORMATION MATRIX RELATES STRESS AT TRIANGLE VERTICES
C  IN LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE LOCAL SYSTEM.
C  ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C     (SIGMA-X,SIGMA-Y,TAU-XY) JOINT 1, THEN JOINT 2, 3.
C  WHERE SIGMA IS NORMAL STRESS AND TAU IS SHEAR STRESS.
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
C  WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C  X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
C  LOCAL COORDINATE ORDER IS
C     (DX,DY,TZ) JOINT 1, THEN JOINT 2, 3.
C  WHERE DX,DY ARE TRANSLATIONS AND TZ IS ROTATION.
C  CALLS FORMA SUBROUTINES BTABA AND MULTA.
C  DEVELOPED BY CS BODLEY, WA BENFIELD. MARCH 1973.
C  LAST REVISION BY CS BODLEY.  SEPTEMBER 1973.
C
C     SUBROUTINE ARGUMENTS
C  X2     = INPUT  LOCAL X COORDINATE LOCATION OF JOINT 2.
C  X3     = INPUT  LOCAL X COORDINATE LOCATION OF JOINT 3.
C  Y3     = INPUT  LOCAL Y COORDINATE LOCATION OF JOINT 3.
C  TH     = INPUT  PLATE THICKNESS.
C  E      = INPUT  YOUNGS MODULUS OF ELASTICITY.
C  ANU    = INPUT  POISSONS RATIO. (E/2G)-1.
C  Z      = OUTPUT STIFFNESS MATRIX. SIZE(9,9).
C  T      = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(9,9).
C  R      = INPUT  MATRIX WORK SPACE. SIZE(8,9).
C  KZ     = INPUT  ROW DIMENSION OF Z  IN CALLING PROGRAM. MIN=9.
C  KT     = INPUT  ROW DIMENSION OF T IN CALLING PROGRAM. MIN=9.
C  KR     = INPUT  ROW DIMENSION OF R IN CALLING PROGRAM. MIN=8.
C
      DO 5 I=1,9
      DO 5 J=1,9
    5 T(I,J) = 0.0
      DO 10 I=1,9
      DO 10 J=1,9
   10 Z(I,J) = 0.0
      IF (TH .LE. 0.0) RETURN
      X22 = X2*X2
      Y32 = Y3*Y3
      X2Y3 = X2*Y3
      SE1 = X3/X2
      G = E/(2. + 2.*ANU)
      DD = E*TH/(1. - ANU**2)
      DNU = DD*ANU
      DG = G*TH
C
```

```
      DO 15 I=1,8
      DO 15 J=1,9
   15 R(I,J) = 0.
C
      F00 = X2Y3/2.
      F10 = X2Y3*(1. + SE1)/6.
      F01 = X2Y3/6.
      F20 = X2Y3*(1. + SE1 + SE1**2)/12.
      F11 = X2Y3*(1. + 2.*SE1)/24.
      F02 = X2Y3/12.
C
      Z(1,1) = DD*F00/X22
      Z(1,3) = DD*F01/X22
      Z(1,6) = DNU*F00/X2Y3
      Z(1,8) = DNU*F10/X2Y3
      Z(2,2) = DG*F00/Y32
      Z(2,3) = DG*F10/Y32
      Z(2,4) = 2.*DG*F01/Y32
      Z(2,5) = DG*F00/X2Y3
      Z(2,7) = 2.*DG*F10/X2Y3
      Z(2,8) = DG*F01/X2Y3
      Z(3,3) = DD*F02/X22 + DG*F20/Y32
      Z(3,4) = 2.*DG*F11/Y32
      Z(3,5) = DG*F10/X2Y3
      Z(3,6) = DNU*F01/X2Y3
      Z(3,7) = 2.*DG*F20/X2Y3
      Z(3,8) = DNU*F11/X2Y3 + DG*F11/X2Y3
      Z(4,4) = 4.*DG*F02/Y32
      Z(4,5) = 2.*DG*F01/X2Y3
      Z(4,7) = 4.*DG*F11/X2Y3
      Z(4,8) = 2.*DG*F02/X2Y3
      Z(5,5) = DG*F00/X22
      Z(5,7) = 2.*DG*F10/X22
      Z(5,8) = DG*F01/X22
      Z(6,6) = DD*F00/Y32
      Z(6,8) = DD*F10/Y32
      Z(7,7) = 4.*DG*F20/X22
      Z(7,8) = 2.*DG*F11/X22
      Z(8,8) = DD*F20/Y32 + DG*F02/X22
      DO 20 I=1,8
      DO 20 J=I,8
   20 Z(J,I) = Z(I,J)
C
      R(1,1) = -1.
      R(1,4) = 1.
      R(2,1) = SE1 - 1.
      R(2,3) = -Y3
      R(2,4) = -SE1
      R(2,7) = 1.
      R(2,9) = Y3
      R(3,3) = Y3
      R(3,6) = -Y3
      R(4,3) = Y3*(1. - SE1)
      R(4,6) = Y3*SE1
      R(4,9) = -Y3
```

```
      R(5,2) = -1.
      R(5,3) = X2
      R(5,5) = 1.
      R(5,6) = -X2
      R(6,2) = SE1 - 1.
      R(6,5) = -SE1
      R(6,6) = X3
      R(6,8) = 1.
      R(6,9) = -X3
      R(7,3) = -X2
      R(7,6) = X2
      R(8,3) = X2*(SE1 - 1.)
      R(8,6) = -X3
      R(8,9) = X2
C
      CALL BTABA (Z,R,8,9,KZ,KR)
C
      D11 = DD/TH
      D12 = ANU*D11
      D33 = G
      XE(1) = 0.
      XE(2) = 1.
      XE(3) = SE1
      ET(1) = 0.
      ET(2) = 0.
      ET(3) = 1.
      DO 30 I=1,3
      K1 = 3*I - 2
      K2 = K1 + 1
      K3 = K1 + 2
      T(K1,1) = D11/X2
      T(K1,3) = D11*ET(I)/X2
      T(K1,6) = D12/Y3
      T(K1,8) = D12*XE(I)/Y3
      T(K2,1) = D12/X2
      T(K2,3) = D12*ET(I)/X2
      T(K2,6) = D11/Y3
      T(K2,8) = D11*XE(I)/Y3
      T(K3,2) = D33/Y3
      T(K3,3) = D33*XE(I)/Y3
      T(K3,4) = 2.*D33*ET(I)/Y3
      T(K3,5) = D33/X2
      T(K3,7) = 2.*D33*XE(I)/X2
   30 T(K3,8) = [illegible]3*ET(I)/X2
      CALL MULT  (T,R,9,8,9,KT,KR)
C
      RETURN
      END
```

```
      SUBROUTINE K2B1 (X2,X3,Y3,TH,E,ANU,Z,TS,T,KZ,KTS,KT)
      DIMENSION Z(KZ,1),TS(KTS,1),T(KT,1)
      DIMENSION R(10,10),IVEC(10),COEF(9),XE(3),ET(3)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     STIFFNESS MATRIX,
C     STRESS TRANSFORMATION MATRIX,
C  FOR A BENDING TRIANGLE PLATE ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  CUBIC DISPLACEMENT (LINEAR CURVATURE) FIELD IS USED.
C  STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C  STRESS TRANSFORMATION MATRIX RELATES STRESS AT JOINTS IN LOCAL
C  COORDINATE SYSTEM TO DEFLECTIONS IN THE LOCAL SYSTEM.
C  ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C     (SIGMA-X,SIGMA-Y,TAU-XY) FOR (Z=TH/2) AT JOINT 1, THEN JOINT 2,3,
C     (SIGMA-X,SIGMA-Y,TAU-XY) FOR (Z=-TH/2) AT JOINT 1, THEN JOINT 2,3.
C  WHERE SIGMA IS NORMAL STRESS AND TAU IS SHEAR STRESS.
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
C  WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C  X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
C  LOCAL COORDINATE ORDER IS
C     (DZ,TX,TY) JOINT 1, THEN JOINT 2, 3.
C  WHERE DZ IS TRANSLATION AND TX,TY ARE ROTATIONS.
C  CALLS FORMA SUBROUTINES BTABA AND MULTA.
C  DEVELOPED BY CS BODLEY. MARCH 1973.
C  LAST REVISION BY CS BODLEY.  SEPTEMBER 1973.
C
C     SUBROUTINE ARGUMENTS
C  X2      = INPUT  LOCAL X COORDINATE LOCATION OF JOINT 2.
C  X3      = INPUT  LOCAL X COORDINATE LOCATION OF JOINT 3.
C  Y3      = INPUT  LOCAL Y COORDINATE LOCATION OF JOINT 3.
C  TH      = INPUT  PLATE THICKNESS.
C  E       = INPUT  YOUNGS MODULUS OF ELASTICITY.
C  ANU     = INPUT  POISSONS RATIO. (E/2G)-1.
C  Z       = OUTPUT STIFFNESS MATRIX. SIZE(9,9).
C  TS      = OUTPUT LOCAL STRESS TRANSFORMATION MATRIX. SIZE(18,9).
C  T       = INPUT  MATRIX WORK SPACE. SIZE(10,10).
C  KZ      = INPUT  ROW DIMENSION OF Z  IN CALLING PROGRAM. MIN=9.
C  KTS     = INPUT  ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=18.
C  KT      = INPUT  ROW DIMENSION OF T  IN CALLING PROGRAM. MIN=10.
C
      DO 10 I=1,9
      DO 10 J=1,9
   10 Z(I,J) = 0.0
      DO 11 I=1,18
      DO 11 J=1,9
   11 TS(I,J) = 0.0
      IF (TH .LE. 0.0) RETURN
C
      DO 12 I=1,10
      DO 12 J=1,10
   12 T(I,J) = 0.0
      X22 = X2*X2
      X24 = X22*X22
      Y32 = Y3*Y3
      Y34 = Y32*Y32
```

```
      SE1 = X3/X2
      SE2 = SE1*SE1
      SE3 = SE2*SE1
      SE4 = SE3*SE1
      SEC1 = (1. + SE1)/3.
      SEC2 = SEC1**2
      SEC3 = SEC1**3
      G = E/(2. + 2.*ANU)
      DD = (E*TH**3)/(12.*(1.-ANU**2))
      DNU = DD*ANU
      DG = (G*TH**3)/12.
      AL = DD/X[illegible]
      BE = DNU/(X22*Y32)
      GA = DD/Y34
      DE = 4.*DG/(X22*Y32)
C
      T(1,1) = 1.
      T(2,3) = 1.
      T(3,2) = 1.
      T(4,1) = 1.
      T(4,2) = 1.
      T(4,4) = 1.
      T(4,7) = 1.
      T(5,3) = 1.
      T(5,5) = 1.
      T(5,8) = 1.
      T(6,2) = 1.
      T(6,4) = 2.
      T(6,7) = 3.
      T(7,1) = 1.
      T(7,2) = SE1
      T(7,3) = 1.
      T(7,4) = SE2
      T(7,5) = SE1
      T(7,6) = 1.
      T(7,7) = SE3
      T(7,8) = SE2
      T(7,9) = SE1
      T(7,10) = 1.
      T(8,3) = 1.
      T(8,5) = SE1
      T(8,6) = 2.
      T(8,8) = SE2
      T(8,9) = 2.*SE1
      T(8,10) = 3.
      T(9,2) = 1.
      T(9,4) = 2.*SE1
      T(9,5) = 1.
      T(9,7) = 3.*SE2
      T(9,8) = 2.*SE1
      T(9,9) = 1.
      T(10,1) = 1.
      T(10,2) = SEC1
      T(10,3) = 1./3.
      T(10,4) = SEC2
```

```
      T(10,5) = SEC1/3.
      T(10,6) = 1./9.
      T(10,7) = SEC3
      T(10,8) = SEC2/3.
      T(10,9) = SEC1/9.
      T(10,10) = 1./27.
C
      DO 5 I=1,10
      DO 7 J=1,10
    7 R(I,J) = 0.
    5 R(I,I) = 1.
C
      DO 100 L=1,10
      JBIG = 1
      A1 = ABS(T(L,1))
      DO 15 J=2,10
      A2 = ABS(T(L,J))
      IF (A2 .LT. A1) GO TO 15
      A1 = A2
      JBIG = J
   15 CONTINUE
      IVEC(L) = JBIG
      ALJBIG = T(L,JBIG)
      DO 17 J=1,10
      T(L,J) = T(L,J)/ALJBIG
   17 R(L,J) = R(L,J)/ALJBIG
      DO 25 I=1,10
      AIJBIG = T(I,JBIG)
      IF (I .EQ. L) GO TO 25
      DO 30 J=1,10
      T(I,J) = T(I,J) - AIJBIG*T(L,J)
   30 R(I,J) = R(I,J) - AIJBIG*R(L,J)
   25 CONTINUE
  100 CONTINUE
C
      DO 40 I=1,10
      IR = IVEC(I)
      DO 40 J=1,10
   40 T(IR,J) = R(I,J)
      DO 50 I=1,10
      DO 50 J=1,10
   50 R(I,J) = T(I,J)
C
      DO 20 I=1,10
      R(I,2) =  Y3*R(I,2)
      R(I,3) = -X2*R(I,3)
      R(I,5) =  Y3*R(I,5)
      R(I,6) = -X2*R(I,6)
      R(I,8) =  Y3*R(I,8)
   20 R(I,9) = -X2*R(I,9)
C
      COEF(1) = 1./3.
      COEF(2) = Y3/18.
      COEF(3) = -(X2+X3)/18.
      COEF(4) = 1./3.
```

```
      COEF(5) = Y3/18.
      COEF(6) = (2.*X2 - X3)/18.
      COEF(7) = 1./3.
      COEF(8) = -Y3/9.
      COEF(9) = (2.*X3 - X2)/18.
      DO 80 I=1,10
      DO 80 J=1,9
   80 R(I,J) = R(I,J) + R(I,10)*COEF(J)
C
      DO 55 I=1,10
      DO 55 J=1,10
   55 T(I,J) = 0.
C
      F00 = X2*Y3/2.
      F10 = X2*Y3*(1. + SE1)/6.
      F01 = X2*Y3/6.
      F20 = X2*Y3*(1. + SE1 + SE2)/12.
      F11 = X2*Y3*(1. + 2.*SE1)/24.
      F02 = X2*Y3/12.
C
      T(4,4) = 4.*AL*F00
      T(4,6) = 4.*BE*F00
      T(4,7) = 12.*AL*F10
      T(4,8) = 4.*AL*F01
      T(4,9) = 4.*BE*F10
      T(4,10) = 12.*BE*F01
      T(5,5) = DE*F00
      T(5,8) = 2.*DE*F10
      T(5,9) = 2.*DE*F01
      T(6,6) = 4.*GA*F00
      T(6,7) = 12.*BE*F10
      T(6,8) = 4.*BE*F01
      T(6,9) = 4.*GA*F10
      T(6,10) = 12.*GA*F01
      T(7,7) = 36.*AL*F20
      T(7,8) = 12.*AL*F11
      T(7,9) = 12.*BE*F20
      T(7,10) = 36.*BE*F11
      T(8,8) = 4.*AL*F02 + 4.*DE*F20
      T(8,9) = 4.*BE*F11 + 4.*DE*F11
      T(8,10) = 12.*BE*F02
      T(9,9) = 4.*GA*F20 + 4.*DE*F02
      T(9,10) = 12.*GA*F11
      T(10,10) = 36.*GA*F02
C
      DO 60 I=1,10
      DO 60 J=I,10
   60 T(J,I) = T(I,J)
      CALL BTABA (T,R,10,9,KT,10)
      DO 85 I=1,9
      DO 85 J=1,9
   85 Z(I,J) = T(I,J)
C
      DO 73 I=1,9
      DO 73 J=1,10
```

```
73 T(I,J) = 0.0
   D11 = -6.*DD/((X2*TH)**2)
   D21 = ANU*D11
   D22 = -6.*DD/((Y3*TH)**2)
   D12 = ANU*D22
   D33 = -12.*DG/((X2*Y3)*TH**2)
   XE(1) = 0.
   XE(2) =1.
   XE(3) =SE1
   ET(1) = 0.
   ET(2) = 0.
   ET(3) =1.
   DO 75 I=1,3
   K1 = 3*I - 2
   K2 = K1 + 1
   K3 = K1 + 2
   T(K1,4) = 2.*D11
   T(K1,6) = 2.*D12
   T(K1,7) = 6.*D11*XE(I)
   T(K1,8) = 2.*D11*ET(I)
   T(K1,9) = 2.*D12*XE(I)
   T(K1,10)= 6.*D12*ET(I)
   T(K2,4) = 2.*D21
   T(K2,6) = 2.*D22
   T(K2,7) = 6.*D21*XE(I)
   T(K2,8) = 2.*D21*ET(I)
   T(K2,9) = 2.*D22*XE(I)
   T(K2,10)= 6.*D22*ET(I)
   T(K3,5) = D33
   T(K3,8) = 2.*D33*XE(I)
75 T(K3,9) = 2.*D33*ET(I)
   CALL MULTA  (T,R,S,10,9,KT,10)
   DO 77 I=1,9
   IP9 = I + 9
   DO 77 J=1,9
   TS(I,J) = T(I,J)
77 TS(IP9,J) = -TS(I,J)
C
   RETURN
   END
```

```
      SUBROUTINE K3C1  (X3,Y3,TH,G,Z,T,KZ,KT)
      DIMENSION Z(KZ,1), T(KT,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     STIFFNESS MATRIX,
C     STRESS TRANSFORMATION MATRIX,
C  FOR A RECTANGULAR SHEAR PANEL ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  LINEAR DISPLACEMENT (CONSTANT STRAIN) FIELD IS USED.
C  STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C  STRESS TRANSFORMATION MATRIX RELATES PANEL SHEAR STRESS (CONSTANT)
C  IN LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE LOCAL SYSTEM.
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE PANEL TO LIE IN AN X-Y PLANE
C  WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C  X AXIS, JOINT 3 IS IN THE POSITIVE X,Y DIRECTION, AND JOINT 4 LIES
C  ALONG THE POSITIVE Y AXIS.
C  LOCAL COORDINATE ORDER IS
C     DX1,DX2,DX3,DX4, DY1,DY2,DY3,DY4
C  WHERE DX,DY ARE TRANSLATIONS.
C  DEVELOPED BY  RL WOHLEN. APRIL 1974.
C
C     SUBROUTINE ARGUMENTS
C  X3      = INPUT  LOCAL X COORDINATE LOCATION OF JOINT 3.
C  Y3      = INPUT  LOCAL Y COORDINATE LOCATION OF JOINT 3.
C  TH      = INPUT  PANEL THICKNESS.
C  G       = INPUT  SHEAR MODULUS OF ELASTICITY.
C  Z       = OUTPUT STIFFNESS MATRIX. SIZE(8,8).
C  T       = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(1,8).
C  KZ      = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=8.
C  KT      = INPUT  ROW DIMENSION OF T IN CALLING PROGRAM. MIN=1.
C
C  STIFFNESS MATRIX.
      C = TH*G/4.
      A = C*X3/Y3
      B = C*Y3/X3
      Z(1,1) = A
      Z(1,2) = A
      Z(1,3) =-A
      Z(1,4) =-A
      Z(1,5) = C
      Z(1,6) =-C
      Z(1,7) =-C
      Z(1,8) = C
      Z(2,2) = A
      Z(2,3) =-A
      Z(2,4) =-A
      Z(2,5) = C
      Z(2,6) =-C
      Z(2,7) =-C
      Z(2,8) = C
      Z(3,3) = A
      Z(3,4) = A
      Z(3,5) =-C
      Z(3,6) = C
      Z(3,7) = C
      Z(3,8) =-C
```

```
      Z(4,4) = A
      Z(4,5) =-C
      Z(4,6) = C
      Z(4,7) = C
      Z(4,8) =-C
      Z(5,5) = B
      Z(5,6) =-B
      Z(5,7) =-B
      Z(5,8) = B
      Z(6,6) = B
      Z(6,7) = B
      Z(6,8) =-B
      Z(7,7) = B
      Z(7,8) =-B
      Z(8,8) = B
C   SYMMETRIZE LOWER HALF.
      DO 10 J=1,8
      DO 10 I=J,8
   10 Z(I,J) = Z(J,I)
C
C   STRESS TRANSFORMATION MATRIX.
      DO 20 J=1,8
   20 T(1,J) = 2.*Z(3,J)/(TH*X3)
C
      RETURN
      END
```

```
      SUBROUTINE KGRAV (CJ,JM    ,EV,A,W,KW,KCJ)
      DIMENSION CJ(KCJ ,1), JM(     1), EV(1),            W(KW,1)
      DIMENSION E(3,9),R12(3),R13(3),VN(3),F(3,3)
      DATA KEF / 3 /
C
C  SUBROUTINE TO DERIVE STIFFNESS MATRIX FOR A TRIANGULAR GRAVITY ELEMENT.
C  CALLS FORMA SUBROUTINES MULTA ,MULTB ,VCROSS.
C  DEVELOPED BY C S BODLEY.  FEBRUARY 1974.
C  LAST REVISION BY C S BODLEY.  NOVEMBER 1974.
C      SUBROUTINE ARGUMENTS
C  CJ     = INPUT  MATRIX OF JOINT COORDINATES. SIZE (3,4).
C  JM     = INPUT  VECTOR OF JOINTS DEFINING A TRIANGLE. SIZE (3).
C  EV     = INPUT  VECTOR NORMALIZED GRAVITY. SIZE = 3.
C  A      = OUTPUT AREA.
C  W      = OUTPUT STIFFNESS MATRIX.
C  KW     = INPUT  ROW DIMENSION SIZE OF W IN CALLING PROGRAM. MIN=9.
C  KCJ    = INPUT  ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C
      J1 = JM(1   )
      J2 = JM(2   )
      J3 = JM(3   )
      DO 5 I=1,9
      DO 5 J=1,3
      W(I,J) = 0.
    5 E(J,I) = 0.
      DO 7 I=1,3
      R12(I) = CJ(I,J2) - CJ(I,J1)
      R13(I) = CJ(I,J3) - CJ(I,J1)
      DO 8 J=1,3
    8 F(I,J) = 1.
    7 F(I,I) = 2.
C
      CALL VCROSS (R12,R13,VN,VAMAG,VBMAG,A,SINAB)
      DO 10 I=1,3
   10 VN(I) = VN(I)/A
      ACUM = 0.0
      DO 15 I=1,3
      I1 = 3*I - 3
      ACUM = ACUM + VN(I)*EV(I)
      DO 15 J=1,3
      E(I,I1+J) = VN(J)
   15 W(I1+J,I) = VN(J)
      CALL MULTB  (F,E,3,3,9,KEF,KEF)
      CALL MULTA (W,E,9,3,9,KW,KEF)
      A = A*ACUM*ACUM*ACUM
C
      RETURN
      END
```

```
      SUBROUTINE M1A1   (A1,A2,RL,RO,Z,KZ)
      DIMENSION Z(KZ,1)
C
C   SUBROUTINE TO CALCULATE FINITE ELEMENT...
C      LUMPED MASS MATRIX
C   FOR AN AXIAL ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.
C   ROD MAY BE LINEARLY TAPERED OR UNIFORM.
C   MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C   THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C   WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C   LOCAL COORDINATE ORDER IS
C      DX1,DX2
C   WHERE DX IS TRANSLATION.
C   DEVELOPED BY  RL WOHLEN.  JANUARY 1973.
C   LAST REVISION BY RL WOHLEN.  SEPTEMBER 1973.
C
C      SUBROUTINE ARGUMENTS
C   A1 = INPUT  CROSS-SECTION AREA AT ROD END 1.
C   A2 = INPUT  CROSS-SECTION AREA AT ROD END 2.
C   RL = INPUT  ROD LENGTH.
C   RO = INPUT  MASS DENSITY.
C   Z  = OUTPUT MASS MATRIX. SIZE(2,2).
C   KZ = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C
      W1 = A1*RL*RO/6.
      W2 = A2*RL*RO/6.
      Z(1,1) = 2.*W1 +    W2
      Z(1,2) = 0.
      Z(2,1) = 0.
      Z(2,2) =    W1 + 2.*W2
C
      RETURN
      END
```

```
      SUBROUTINE M1A2   (A1,A2,RL,RO,Z,KZ)
      DIMENSION Z(KZ,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     CONSISTENT MASS MATRIX
C  FOR AN AXIAL ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  ROD MAY BE LINEARLY TAPERED OR UNIFORM.
C  LINEAR DISPLACEMENT FUNCTION ASSUMED.
C  MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C  WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C  LOCAL COORDINATE ORDER IS
C     DX1,DX2
C  WHERE DX IS TRANSLATION.
C  DEVELOPED BY  RL WOHLEN.  SEPTEMBER 1972.
C  LAST REVISION BY RL WOHLEN.  SEPTEMBER 1973.
C
C     SUBROUTINE ARGUMENTS
C  A1 = INPUT  CROSS-SECTION AREA AT ROD END 1.
C  A2 = INPUT  CROSS-SECTION AREA AT ROD END 2.
C  RL = INPUT  ROD LENGTH.
C  RO = INPUT  MASS DENSITY.
C  Z  = OUTPUT MASS MATRIX. SIZE(2,2).
C  KZ = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C
      W1 = A1*RL*RO/12.
      W2 = A2*RL*RO/12.
      Z(1,1) = 3.*W1 +    W2
      Z(1,2) =    W1 +    W2
      Z(2,1) = Z(1,2)
      Z(2,2) =    W1 + 3.*W2
C
      RETURN
      END
```

```
      SUBROUTINE M1B1   (A1,A2,RL,RO,Z,KZ)
      DIMENSION Z(KZ,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     LUMPED MASS MATRIX
C  FOR A BENDING BEAM ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  BEAM MAY BE LINEARLY TAPERED OR UNIFORM.
C  MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE BEAM TO LIE IN THE X-Z PLANE
C  WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C  LOCAL COORDINATE ORDER IS
C     DZ1,DZ2,TY1,TY2
C  WHERE DZ IS TRANSLATION AND TY IS ROTATION.
C  DEVELOPED BY  RL WOHLEN.  FEBRUARY 1973.
C  LAST REVISION BY RL WOHLEN.  SEPTEMBER 1973.
C
C     SUBROUTINE ARGUMENTS
C  A1 = INPUT  CROSS-SECTION AREA AT BEAM END 1.
C  A2 = INPUT  CROSS-SECTION AREA AT BEAM END 2.
C  RL = INPUT  BEAM LENGTH.
C  RO = INPUT  MASS DENSITY.
C  Z  = OUTPUT MASS MATRIX. SIZE(4,4).
C  KZ = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=4.
C
      W1 = A1*RL*RO/6.
      W2 = A2*RL*RO/6.
      DO 10 J=1,4
      DO 10 I=1,4
   10 Z(I,J) = 0.0
      Z(1,1) = 2.*W1 +    W2
      Z(2,2) =     W1 + 2.*W2
      Z(3,3) = (A1*RO*RL**3)/24.
      Z(4,4) = (A2*RO*RL**3)/24.
C
      RETURN
      END
```

```
      SUBROUTINE M1B2   (A1,A2,RL,RO,Z,KZ)
      DIMENSION Z(KZ,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     CONSISTENT MASS MATRIX
C  FOR A BENDING BEAM ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  BEAM MAY BE LINEARLY TAPERED OR UNIFORM.
C  CUBIC DISPLACEMENT FUNCTION ASSUMED.
C  MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE BEAM TO LIE IN THE X-Z PLANE
C  WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C  LOCAL COORDINATE ORDER IS
C     DZ1,DZ2,TY1,TY2
C  WHERE DZ IS TRANSLATION AND TY IS ROTATION.
C  DEVELOPED BY  RL WOHLEN.  FEBRUARY 1973.
C  LAST REVISION BY RL WOHLEN.  SEPTEMBER 1973.
C
C     SUBROUTINE ARGUMENTS
C  A1 = INPUT  CROSS-SECTION AREA AT BEAM END 1.
C  A2 = INPUT  CROSS-SECTION AREA AT BEAM END 2.
C  RL = INPUT  BEAM LENGTH.
C  RO = INPUT  MASS DENSITY.
C  Z  = OUTPUT MASS MATRIX. SIZE(4,4).
C  KZ = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=4.
C
      W1 = A1*RL*RO/840.
      W2 = A2*RL*RO/840.
      RL2 = RL**2
      Z(1,1) =  240.*W1 +  72.*W2
      Z(1,2) =   54.*W1 +  54.*W2
      Z(2,2) =   72.*W1 + 240.*W2
      Z(1,3) =-( 30.*W1 +  14.*W2)*RL
      Z(1,4) = ( 14.*W1 +  12.*W2)*RL
      Z(2,3) =-( 12.*W1 +  14.*W2)*RL
      Z(2,4) = ( 14.*W1 +  30.*W2)*RL
      Z(3,3) = (  5.*W1 +   3.*W2)*RL2
      Z(3,4) =-(  3.*W1 +   3.*W2)*RL2
      Z(4,4) = (  3.*W1 +   5.*W2)*RL2
      DO 10 J=1,4
      DO 10 I=J,4
   10 Z(I,J) = Z(J,I)
C
      RETURN
      END
```

```
      SUBROUTINE M1C1   (PI1,PI2,RL,RO,Z,KZ)
      DIMENSION Z(KZ,1)
C
C   SUBROUTINE TO CALCULATE FINITE ELEMENT...
C      LUMPED MASS MATRIX
C   FOR A TORSION ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.
C   ROD MAY BE LINEARLY TAPERED OR UNIFORM.
C   MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C   THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C   WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C   LOCAL COORDINATE ORDER IS
C      TX1,TX2
C   WHERE TX IS ROTATION.
C   DEVELOPED BY  RL WOHLEN.  FEBRUARY 1973.
C   LAST REVISION BY RL WOHLEN.  SEPTEMBER 1973.
C
C      SUBROUTINE ARGUMENTS
C   PI1 = INPUT  CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT ROD END 1.
C   PI2 = INPUT  CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT ROD END 2.
C   RL  = INPUT  ROD LENGTH.
C   RO  = INPUT  MASS DENSITY.
C   Z   = OUTPUT MASS MATRIX. SIZE(2,2).
C   KZ  = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C
      W1 = PI1*RL*RO/6.
      W2 = PI2*RL*RO/6.
      Z(1,1) = 2.*W1 +    W2
      Z(1,2) = 0.
      Z(2,1) = 0.
      Z(2,2) =    W1 + 2.*W2
C
      RETURN
      END
```

```
      SUBROUTINE M1C2   (PI1,PI2,RL,RO,Z,KZ)
      DIMENSION Z(KZ,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     CONSISTENT MASS MATRIX
C  FOR A TORSION ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  ROD MAY BE LINEARLY TAPERED OR UNIFORM.
C  LINEAR DISPLACEMENT FUNCTION ASSUMED.
C  MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C  WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C  LOCAL COORDINATE ORDER IS
C     TX1,TX2
C  WHERE TX IS ROTATION.
C  DEVELOPED BY  RL WOHLEN.  FEBRUARY 1973.
C  LAST REVISION BY RL WOHLEN.  SEPTEMBER 1973.
C
C     SUBROUTINE ARGUMENTS
C  PI1 = INPUT  CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT ROD END 1.
C  PI2 = INPUT  CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT ROD END 2.
C  RL  = INPUT  ROD LENGTH.
C  RO  = INPUT  MASS DENSITY.
C  Z   = OUTPUT MASS MATRIX. SIZE(2,2).
C  KZ  = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C
      W1 = PI1*RL*RO/12.
      W2 = PI2*RL*RO/12.
      Z(1,1) = 3.*W1 +    W2
      Z(1,2) =    W1 +    W2
      Z(2,1) = Z(1,2)
      Z(2,2) =    W1 + 3.*W2
C
      RETURN
      END
```

M2A1

```
      SUBROUTINE M2A1    (X2,Y3,TH,RO,Z,KZ)
      DIMENSION Z(KZ,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     LUMPED MASS MATRIX,
C  FOR A MEMBRANE TRIANGLE PLATE ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
C  WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C  X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
C  LOCAL COORDINATE ORDER IS
C     (DX,DY,TZ) JOINT 1, THEN JOINT 2, 3.
C  WHERE DX,DY ARE TRANSLATIONS AND TZ IS ROTATION.
C  DEVELOPED BY WA BENFIELD. FEBRUARY 1973.
C  LAST REVISION BY RL WOHLEN.  SEPTEMBER 1973.
C
C     SUBROUTINE ARGUMENTS
C  X2      = INPUT  LOCAL X COORDINATE LOCATION OF JOINT 2.
C  Y3      = INPUT  LOCAL Y COORDINATE LOCATION OF JOINT 3.
C  TH      = INPUT  PLATE THICKNESS.
C  RO      = INPUT  MASS DENSITY.
C  Z       = OUTPUT MASS MATRIX. SIZE(9,9).
C  KZ      = INPUT  ROW DIMENSION OF Z  IN CALLING PROGRAM. MIN=9.
C
      AREA = 0.5*X2*Y3
      CM = (RO*TH*AREA)/3.0
      DO 10 I=1,9
      DO 10 J=1,9
   10 Z(I,J) = 0.0
      DO 20 I=1,9
   20 Z(I,I) = CM
      RETURN
      END
```

```
      SUBROUTINE M2A2 (X2,X3,Y3,TH,RHO,Z,T,R,KZ,KT,KR)
      DIMENSION Z(KZ,1),T(KT,1),R(KR,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C      CONSISTENT MASS MATRIX,
C  FOR A MEMBRANE TRIANGLE PLATE ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  QUADRATIC DISPLACEMENT (LINEAR STRAIN) FIELD IS USED.
C  MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
C  WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C  X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
C  LOCAL COORDINATE ORDER IS
C      (DX,DY,TZ) JOINT 1, THEN JOINT 2, 3.
C  WHERE DX,DY ARE TRANSLATIONS AND TZ IS ROTATION.
C  CALLS FORMA SUBROUTINES ETAEA.
C  DEVELOPED BY CS BODLEY.  MARCH 1973.
C  LAST REVISION BY WA BENFIELD.  SEPTEMBER 1973.
C
C      SUBROUTINE ARGUMENTS
C  X2      = INPUT  LOCAL X COORDINATE LOCATION OF JOINT 2.
C  X3      = INPUT  LOCAL X COORDINATE LOCATION OF JOINT 3.
C  Y3      = INPUT  LOCAL Y COORDINATE LOCATION OF JOINT 3.
C  TH      = INPUT  PLATE THICKNESS.
C  RHO     = INPUT  MASS DENSITY.
C  Z       = OUTPUT MASS MATRIX. SIZE(9,9).
C  T       = INPUT  MATRIX WORK SPACE. SIZE(10,10).
C  R       = INPUT  MATRIX WORK SPACE. SIZE(10,10).
C  KZ      = INPUT  ROW DIMENSION OF Z  IN CALLING PROGRAM. MIN=9.
C  KT      = INPUT  ROW DIMENSION OF T  IN CALLING PROGRAM. MIN=10.
C  KR      = INPUT  ROW DIMENSION OF R  IN CALLING PROGRAM. MIN=10.
C
      SE1 = X3/X2
      SE2 = SE1*SE1
      SE3 = SE2*SE1
      SE4 = SE3*SE1
      X2Y3 = X2*Y3*RHO*TH
C
      DO 10 I=1,10
      DO 10 J=1,10
      T(I,J) = 0.
   10 R(I,J) = 0.
C
      F00 = X2Y3/2.
      F10 = X2Y3*(1. + SE1)/6.
      F01 = X2Y3/6.
      F20 = X2Y3*(1. + SE1 + SE2)/12.
      F11 = X2Y3*(1. + 2.*SE1)/24.
      F02 = X2Y3/12.
      F30 = X2Y3*(1. + SE1 + SE2 + SE3)/20.
      F21 = X2Y3*(1. + 2.*SE1 + 3.*SE2)/60.
      F12 = X2Y3*(1. + 3.*SE1)/60.
      F03 = X2Y3/20.
      F40 = X2Y3*(1. + SE1 + SE2 + SE3 + SE4)/30.
      F31 = X2Y3*(1. + 2.*SE1 + 3.*SE2 + 4.*SE3)/120.
      F22 = X2Y3*(1. + 3.*SE1 + 6.*SE2)/180.
```

```
      F13 = X2Y3*(1. + 4.*SE1)/120.
      F04 = X2Y3/30.
      T(1,1) = F00
      T(1,2) = F10
      T(1,3) = F01
      T(1,4) = F11
      T(1,5) = F02
      T(2,2) = F20
      T(2,3) = F11
      T(2,4) = F21
      T(2,5) = F12
      T(3,3) = F02
      T(3,4) = F12
      T(3,5) = F03
      T(4,4) = F22
      T(4,5) = F13
      T(5,5) = F04
      T(6,6) = F00
      T(6,7) = F10
      T(6,8) = F01
      T(6,9) = F20
      T(6,10) = F11
      T(7,7) =  F20
      T(7,8) = F11
      T(7,9) = F30
      T(7,10) = F21
      T(8,8) = F02
      T(8,9) = F21
      T(8,10) = F12
      T(9,9) = F40
      T(9,10) = F31
      T(10,10) = F22
      DO 30 I=1,10
      DO 30 J=I,10
   30 T(J,I) = T(I,J)
C
      R(1,1) = 1.
      R(2,1) = -1.
      R(2,4) = 1.
      R(3,1) = SE1 - 1.
      R(3,3) = -Y3
      R(3,4) = -SE1
      R(3,7) = 1.
      R(3,9) = Y3
      R(4,3) = Y3
      R(4,6) = -Y3
      R(5,3) = Y3*(1. - SE1)
      R(5,6) = Y3*SE1
      R(5,9) = -Y3
      R(6,2) = 1.
      R(7,2) = -1.
      R(7,3) = Y2
      R(7,5) = 1.
      R(7,6) = -Y2
      R(8,2) = SE1 - 1.
```

```
      R(8,5) = -SE1
      R(8,6) = X3
      R(8,8) = 1.
      R(8,9) = -X3
      R(9,3) = -X2
      R(9,6) = X2
      R(10,3) = X2*(SE1 - 1.)
      R(10,6) = -X3
      R(10,9) = X2
C
      CALL PTAPA (T,R,10,9,KT,KR)
      DO 40 I=1,9
      DO 40 J=1,9
   40 Z(I,J) = T(I,J)
C
      RETURN
      END
```

```
      SUBROUTINE M2B1   (X2,Y3,TH,RO,Z,KZ)
      DIMENSION Z(KZ,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     LUMPED MASS MATRIX,
C  FOR A BENDING TRIANGLE PLATE ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
C  WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C  X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
C  LOCAL COORDINATE ORDER IS
C     (DZ,TX,TY) JOINT 1, THEN JOINT 2, 3.
C  WHERE DZ IS TRANSLATION AND TX,TY ARE ROTATIONS.
C  DEVELOPED BY WA BENFIELD. FEBRUARY 1973.
C  LAST REVISION BY RL WOHLEN.  SEPTEMBER 1973.
C
C     SUBROUTINE ARGUMENTS
C  X2      = INPUT  LOCAL X COORDINATE LOCATION OF JOINT 2.
C  Y3      = INPUT  LOCAL Y COORDINATE LOCATION OF JOINT 3.
C  TH      = INPUT  PLATE THICKNESS.
C  RO      = INPUT  MASS DENSITY.
C  Z       = OUTPUT MASS MATRIX. SIZE(9,9).
C  KZ      = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=9.
C
      AREA = 0.5*X2*Y3
      CM = (RO*TH*AREA)/3.0
      DO 10 I=1,9
      DO 10 J=1,9
   10 Z(I,J) = 0.0
      DO 20 I=1,9
   20 Z(I,I) = CM
      RETURN
      END
```

```
      SUBROUTINE M2B2 (X2,X3,Y3,TH,RHO,Z,T,R,KZ,KT,KR)
      DIMENSION Z(KZ,1),T(KT,1),R(KR,1)
      DIMENSION IVEC(10),COEF(9)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     CONSISTENT MASS MATRIX,
C  FOR A BENDING TRIANGLE PLATE ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  CUBIC DISPLACEMENT (LINEAR CURVATURE) FIELD IS USED.
C  THIS IS NOT THE SO CALLED STRICKLAND ELEMENT.
C  MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
C  WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C  X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
C  LOCAL COORDINATE ORDER IS
C     (DZ,TX,TY) JOINT 1, THEN JOINT 2, 3.
C  WHERE DZ IS TRANSLATION AND TX,TY ARE ROTATIONS.
C  CALLS FORMA SUBROUTINES BTABA.
C  DEVELOPED BY CARL BODLEY MARCH 1973.
C  LAST REVISION BY WA BENFIELD.  SEPTEMBER 1973.
C
C     SUBROUTINE ARGUMENTS
C  X2      = INPUT  LOCAL X COORDINATE LOCATION OF JOINT 2.
C  X3      = INPUT  LOCAL X COORDINATE LOCATION OF JOINT 3.
C  Y3      = INPUT  LOCAL Y COORDINATE LOCATION OF JOINT 3.
C  TH      = INPUT  PLATE THICKNESS.
C  RHO     = INPUT  MASS DENSITY.
C  Z       = OUTPUT MASS MATRIX. SIZE(9,9).
C  T       = INPUT  MATRIX WORK SPACE. SIZE(10,10).
C  R       = INPUT  MATRIX WORK SPACE. SIZE(10,10).
C  KZ      = INPUT  ROW DIMENSION OF Z  IN CALLING PROGRAM. MIN=9.
C  KT      = INPUT  ROW DIMENSION OF T  IN CALLING PROGRAM. MIN=10.
C  KR      = INPUT  ROW DIMENSION OF R  IN CALLING PROGRAM. MIN=10.
C
      SE1 = X3/X2
      SE2 = SE1*SE1
      SE3 = SE2*SE1
      SE4 = SE3*SE1
      SE5 = SE4*SE1
      SE6 = SE5*SE1
      SEC1 = (1. + SE1)/3.
      SEC2 = SEC1**2
      SEC3 = SEC1**3
C
      DO 10 I=1,10
      DO 10 J=1,10
   10 T(I,J) = 0.
C
      T(1,1) = 1.
      T(2,3) = 1.
      T(3,2) = 1.
      T(4,1) = 1.
      T(4,2) = 1.
      T(4,4) = 1.
      T(4,7) = 1.
      T(5,3) = 1.
```

```
      T(5,5) = 1.
      T(5,8) = 1.
      T(6,2) = 1.
      T(6,4) = 2.
      T(6,7) = 3.
      T(7,1) = 1.
      T(7,2) = SE1
      T(7,3) = 1.
      T(7,4) = SE2
      T(7,5) = SE1
      T(7,6) = 1.
      T(7,7) = SE3
      T(7,8) = SE2
      T(7,9) = SE1
      T(7,10) = 1.
      T(8,3) = 1.
      T(8,5) = SE1
      T(8,6) = 2.
      T(8,8) = SE2
      T(8,9) = 2.*SE1
      T(8,10) = 3.
      T(9,2) = 1.
      T(9,4) = 2.*SE1
      T(9,5) = 1.
      T(9,7) = 3.*SE2
      T(9,8) = 2.*SE1
      T(9,9) = 1.
      T(10,1) = 1.
      T(10,2) = SEC1
      T(10,3) = 1./3.
      T(10,4) = SEC2
      T(10,5) = SEC1/3.
      T(10,6) = 1./9.
      T(10,7) = SEC3
      T(10,8) = SEC2/3.
      T(10,9) = SEC1/9.
      T(10,10) = 1./27.
C
      DO 5 I=1,10
      DO 7 J=1,10
    7 R(I,J) = 0.
    5 R(I,I) = 1.
C
      DO 100 L=1,10
      JBIG = 1
      A1 = ABS(T(L,1))
      DO 15 J=2,10
      A2 = ABS(T(L,J))
      IF (A2 .LT. A1) GO TO 15
      A1 = A2
      JBIG = J
   15 CONTINUE
      IVEC(L) = JBIG
      ALJBIG = T(L,JBIG)
      DO 17 J=1,10
```

```
      T(L,J) = T(L,J)/ALJBIG
   17 R(L,J) = R(L,J)/ALJBIG
      DO 25 I=1,10
      AIJBIG = T(I,JBIG)
      IF (I .EQ. L) GO TO 25
      DO 30 J=1,10
      T(I,J) = T(I,J) - AIJBIG*T(L,J)
   30 R(I,J) = R(I,J) - AIJBIG*R(L,J)
   25 CONTINUE
  100 CONTINUE
C
      DO 40 I=1,10
      IR = IVEC(I)
      DO 40 J=1,10
   40 T(IR,J) = R(I,J)
      DO 50 I=1,10
      DO 50 J=1,10
   50 R(I,J) = T(I,J)
C
      DO 20 I=1,10
      R(I,2) =  Y3*R(I,2)
      R(I,3) = -X2*R(I,3)
      R(I,5) =  Y3*R(I,5)
      R(I,6) = -X2*R(I,6)
      R(I,8) =  Y3*R(I,8)
   20 R(I,9) = -X2*R(I,9)
C
      COEF(1) = 1./3.
      COEF(2) = Y3/18.
      COEF(3) = -(X2+X3)/18.
      COEF(4) = 1./3.
      COEF(5) = Y3/18.
      COEF(6) = (2.*X2 - X3)/18.
      COEF(7) = 1./3.
      COEF(8) = -Y3/9.
      COEF(9) = (2.*X3 - X2)/18.
      DO 80 I=1,10
      DO 80 J=1,9
   80 R(I,J) = R(I,J) + R(I,10)*COEF(J)
C
      DO 55 I=1,10
      DO 55 J=1,10
   55 T(I,J) = 0.
C
      X2Y3 = X2*Y3*TH*RHO
      F00 = X2Y3/2.
      F10 = X2Y3*(1. + SE1)/6.
      F01 = X2Y3/6.
      F20 = X2Y3*(1. + SE1 + SE2)/12.
      F11 = X2Y3*(1. + 2.*SE1)/24.
      F02 = X2Y3/12.
      F30 = X2Y3*(1. + SE1 + SE2 + SE3)/20.
      F21 = X2Y3*(1. + 2.*SE1 + 3.*SE2)/60.
      F12 = X2Y3*(1. + 3.*SE1)/60.
      F03 = X2Y3/20.
```

```
      F40 = X2Y3*(1. + SE1 + SE2 + SE3 + SE4)/30.
      F31 = X2Y3*(1. + 2.*SE1 + 3.*SE2 + 4.*SE3)/120.
      F22 = X2Y3*(1. + 3.*SE1 + 6.*SE2)/180.
      F13 = X2Y3*(1. + 4.*SE1)/120.
      F04 = X2Y3/30.
      F50 = X2Y3*(1. + SE1 + SE2 + SE3 + SE4 + SE5)/42.
      F41 = X2Y3*(1. + 2.*SE1 + 3.*SE2 + 4.*SE3 + 5.*SE4)/210.
      F32 = X2Y3*(1. + 3.*SE1 + 6.*SE2 + 10.*SE3)/420.
      F23 = X2Y3*(1. + 4.*SE1 + 10.*SE2)/420.
      F14 = X2Y3*(1. + 5.*SE1)/210.
      F05 = X2Y3/42.
      F60 = X2Y3*(1. + SE1 + SE2 + SE3 + SE4 + SE5 + SE6)/56.
      F51 = X2Y3*(1.+2.*SE1+3.*SE2+4.*SE3+5.*SE4+6.*SE5)/336.
      F42 = X2Y3*(1.+3.*SE1+6.*SE2+10.*SE3+15.*SE4)/840.
      F33 = X2Y3*(1.+4.*SE1+10.*SE2+20.*SE3)/1120.
      F24 = X2Y3*(1.+5.*SE1+15.*SE2)/840.
      F15 = X2Y3*(1.+6.*SE1)/336.
      F06 = X2Y3/56.
C
      T(1,1) = F00
      T(1,2) = F10
      T(1,3) = F01
      T(1,4) = F20
      T(1,5) = F11
      T(1,6) = F02
      T(1,7) = F30
      T(1,8) = F21
      T(1,9) = F12
      T(1,10) = F03
      T(2,2) = F20
      T(2,3) = F11
      T(2,4) = F30
      T(2,5) = F21
      T(2,6) = F12
      T(2,7) = F40
      T(2,8) = F31
      T(2,9) = F22
      T(2,10) = F13
      T(3,3) = F02
      T(3,4) = F21
      T(3,5) = F12
      T(3,6) = F03
      T(3,7) = F31
      T(3,8) = F22
      T(3,9) = F13
      T(3,10) = F04
      T(4,4) = F40
      T(4,5) = F31
      T(4,6) = F22
      T(4,7) = F50
      T(4,8) = F41
      T(4,9) = F32
      T(4,10) = F23
      T(5,5) = F22
      T(5,6) = F13
```

```
      T(5,7) = F41
      T(5,8) = F32
      T(5,9) = F23
      T(5,10) = F14
      T(6,6) = F04
      T(6,7) = F32
      T(6,8) = F23
      T(6,9) = F14
      T(6,10) = F05
      T(7,7) = F60
      T(7,8) = F51
      T(7,9) = F42
      T(7,10) = F33
      T(8,8) = F42
      T(8,9) = F33
      T(8,10) = F24
      T(9,9) = F24
      T(9,10) = F15
      T(10,10) = F06
C
      DO 60 I=1,10
      DO 60 J=I,10
   60 T(J,I) = T(I,J)
      CALL BTABA (T,R,10,9,KT,KR)
      DO 85 I=1,9
      DO 85 J=1,9
   85 Z(I,J) = T(I,J)
C
      RETURN
      END
```

```
      SUBROUTINE M3C1  (X3,Y3,TH,RO,Z,KZ)
      DIMENSION Z(KZ,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     LUMPED MASS MATRIX
C  FOR A RECTANGULAR SHEAR PANEL ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C  THE LOCAL COORDINATE SYSTEM ASSUMES THE PANEL TO LIE IN AN X-Y PLANE
C  WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C  X AXIS, JOINT 3 IS IN THE POSITIVE X,Y DIRECTION, AND JOINT 4 LIES
C  ALONG THE POSITIVE Y AXIS.
C  LOCAL COORDINATE ORDER IS
C     DX1,DX2,DX3,DX4, DY1,DY2,DY3,DY4
C  WHERE DX,DY ARE TRANSLATIONS.
C  DEVELOPED BY  RL WOHLEN. APRIL 1974.
C
C     SUBROUTINE ARGUMENTS
C  X3      = INPUT  LOCAL X COORDINATE LOCATION OF JOINT 3.
C  Y3      = INPUT  LOCAL Y COORDINATE LOCATION OF JOINT 3.
C  TH      = INPUT  PANEL THICKNESS.
C  RO      = INPUT  MASS DENSITY.
C  Z       = OUTPUT MASS MATRIX. SIZE(8,8).
C  KZ      = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=8.
C
      CM = RO*TH*X3*Y3/4.0
      DO 10 J=1,8
      DO 10 I=1,8
   10 Z(I,J) = 0.0
      DO 20 I=1,8
   20 Z(I,I) = CM
C
      RETURN
      END
```

```
      SUBROUTINE MAS1A  (CJ,EJ,A1,A2,RO,NAMEM,Z,KCJ,KEJ,KZ)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(KZ,1)
      DIMENSION E1(3,3), E2(3,3), W(2,2)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     MASS MATRIX
C  FOR AN AXIAL ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  ROD MAY BE LINEARLY TAPERED OR UNIFORM.
C  MASS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C  GLOBAL COORDINATE ORDER IS
C     (U,V,W) JOINT 1, THEN JOINT 2.
C  WHERE U,V,W ARE TRANSLATIONS.
C  EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C  CALLS FORMA SUBROUTINES EULER,M1A1,M1A2,ZZBOMB.
C  DEVELOPED BY  RL WOHLEN.  SEPTEMBER 1972.
C  LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C     SUBROUTINE ARGUMENTS
C  CJ      = INPUT  MATRIX OF GLOBAL X,Y,Z COORDINATES AT ROD JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C                   COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C  EJ      = INPUT  MATRIX OF EULER ANGLES (DEGREES) AT ROD JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C                   COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C  A1      = INPUT  CROSS-SECTION AREA AT ROD END 1.
C  A2      = INPUT  CROSS-SECTION AREA AT ROD END 2.
C  RO      = INPUT  MASS DENSITY.
C  NAMEM   = INPUT  TYPE OF MASS MATRIX WANTED.
C                   = M1, LUMPED.
C                   = M2, CONSISTENT.
C  Z       = OUTPUT MASS MATRIX. SIZE(6,6).
C  KCJ     = INPUT  ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C  KEJ     = INPUT  ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C  KZ      = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=6.
C
C     NERROR  EXPLANATION
C  1 = DIMENSION SIZE EXCEEDED (KZ).
C  2 = NAMEM IMPROPERLY DEFINED.
C
                                                            NERROR=1
      IF (KZ .LT. 6) GO TO 999
      DO 5 J=1,6
      DO 5 I=1,6
    5 Z(I,J) = 0.0
      RL = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
     *                               + (CJ(3,2)-CJ(3,1))**2)
      IF (NAMEM .EQ. 6HM1     ) GO TO 110
      IF (NAMEM .EQ. 6HM2     ) GO TO 120
                                                            NERROR=2
      GO TO 999
C
C  LUMPED.
  110 CALL M1A1   (A1,A2,RL,RO,W,2)
      DO 112 I=1,3
  112 Z(I,I) = W(1,1)
```

```
      DO 114 I=4,6
  114 Z(I,I) = W(2,2)
      RETURN
C
C  CONSISTENT.
  120 CALL M1A2   (A1,A2,RL,RO,W,2)
      DO 122 I=1,3
  122 Z(I,I) = W(1,1)
      CALL EULER  (EJ(1,1),E1,3)
      CALL EULER  (EJ(1,2),E2,3)
      CALL ATXBB  (E1,E2, 3,3,3, 3,3)
      DO 124 I=1,3
      DO 124 J=4,6
      Z(I,J) = W(1,2)*E2(I,J-3)
  124 Z(J,I) = Z(I,J)
      DO 126 I=4,6
  126 Z(I,I) = W(2,2)
      RETURN
C
  999 CALL ZZBOMB (6HMASIA ,NERROR)
      END
```

```
      SUBROUTINE MAS1B (CJ,EJ,A1,A2,PI1,PI2,RO,NAMEM,Z,W,KCJ,KEJ,KZ,KW)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(KZ,1), W(KW,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     MASS MATRIX
C  FOR A COMBINED AXIAL-TORSION-BENDING BAR ELEMENT WITH UNRESTRAINED
C  BOUNDARIES.
C  BAR MAY BE LINEARLY TAPERED OR UNIFORM.
C  MASS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C  GLOBAL COORDINATE ORDER IS
C     (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2
C  WHERE U,V,W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS.
C  EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C  CALLS FORMA SUBROUTINES BTABA,DCOS1B,M1A1,M1A2,M1B1,M1B2,M1C1,M1C2,
C                          ZZBOMB.
C  DEVELOPED BY  RL WOHLEN.  FEBRUARY 1973.
C  LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C     SUBROUTINE ARGUMENTS
C  CJ      = INPUT  MATRIX OF GLOBAL X,Y,Z COORDINATES AT BAR JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C                   COLS 1,2 CORRESPOND TO JOINTS 1,2. COL 3 CORRESPONDS
C                   TO REFERENCE POINT TO DEFINE LOCAL XY PLANE. SIZE(3,3).
C  EJ      = INPUT  MATRIX OF EULER ANGLES (DEGREES) AT BAR JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C                   COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C  A1      = INPUT  CROSS-SECTION AREA AT BAR END 1.
C  A2      = INPUT  CROSS-SECTION AREA AT BAR END 2.
C  PI1     = INPUT  CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT END 1.
C  PI2     = INPUT  CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT END 2.
C  RO      = INPUT  MASS DENSITY.
C  NAMEM   = INPUT  TYPE OF MASS MATRIX WANTED.
C                   = M1, LUMPED.
C                   = M2, CONSISTENT.
C  Z       = OUTPUT MASS MATRIX. SIZE(12,12).
C  W       = INPUT  WORK SPACE MATRIX. SIZE(12,12).
C  KCJ     = INPUT  ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C  KEJ     = INPUT  ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C  KZ      = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=12.
C  KW      = INPUT  ROW DIMENSION OF W IN CALLING PROGRAM. MIN=12.
C
C     NERROR  EXPLANATION
C  1 = DIMENSION SIZE EXCEEDED KZ,KW).
C  2 = NAMEM IMPROPERLY DEFINED.
C
                                                               NERROR=1
      IF (KZ .LT. 12 .OR. KW .LT. 12) GO TO 999
      DO 5 J=1,12
      DO 5 I=1,12
    5 Z(I,J) = 0.0
      RL = SQRT (CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
     *                                + (CJ(3,2)-CJ(3,1))**2)
      IF (NAMEM .EQ. 6HM1     ) GO TO 110
      IF (NAMEM .EQ. 6HM2     ) GO TO 120
                                                               NERROR=2
```

```
      GO TO 999
C
C  AXIAL=M1A1 (LUMPED), TORSION=M1C1 (LUMPED), BENDING=M1B1 (LUMPED).
  110 CALL M1A1   (A1,A2,RL,RO,Z,KZ)
      CALL M1C1   (PI1,PI2,RL,RO,Z(3,3),KZ)
      CALL M1B1   (A1,A2,RL,RO,Z(5,5),KZ)
      CALL M1B1   (A1,A2,RL,RO,Z(9,9),KZ)
      GO TO 300
C
C  AXIAL=M1A2 (LINEAR DISP), TORSION=M1C2 (LINEAR DISP),
C  BENDING=M1B2 (CUBIC DISP).
  120 CALL M1A2   (A1,A2,RL,RO,Z,KZ)
      CALL M1C2   (PI1,PI2,RL,RO,Z(3,3),KZ)
      CALL M1B2   (A1,A2,RL,RO,Z(5,5),KZ)
      DO 125 J=7,8
      DO 125 I=5,6
      Z(I,J) =-Z(I,J)
  125 Z(J,I) =-Z(J,I)
      CALL M1B2   (A1,A2,RL,RO,Z(9,9),KZ)
C
  300 CALL DCOS1F (CJ,EJ,W,KCJ,KEJ,KW)
      CALL HTABA  (Z,W, 12,12, KZ,KW)
      RETURN
C
  999 CALL ZZBOMB (6HMAS1B ,NERROR)
      END
```

```
      SUBROUTINE MAS2   (CJ,EJ,TMAS,RO,NAMEM,Z,W1,W2,KCJ,KEJ,KZ,KW1,KW2)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(KZ,1), W1(KW1,1), W2(KW2,1)
      DIMENSION IVEC(18)
      DATA IVEC/1,2,6,7,8,12,13,14,18,   3,4,5,9,10,11,15,16,17/
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     MASS MATRIX
C  FOR A COMBINED MEMBRANE-BENDING TRIANGLE PLATE ELEMENT WITH
C  UNRESTRAINED BOUNDARIES.
C  MASS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C  GLOBAL COORDINATE ORDER IS
C     (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2, 3.
C  WHERE U,V,W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS.
C  EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C  CALLS FORMA SUBROUTINES ETABA,DCOS2,M2A1,M2A2,M2B1,M2B2,ZZBOMB.
C  DEVELOPED BY WA BENFIELD, RL WOHLEN. FEBRUARY 1973.
C  LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C     SUBROUTINE ARGUMENTS
C  CJ      = INPUT  MATRIX OF GLOBAL X,Y,Z COORDINATES AT TRIANGLE JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C                   COLS 1,2,3 CORRESPOND TO JOINTS 1,2,3. SIZE(3,3).
C  EJ      = INPUT  MATRIX OF EULER ANGLES (DEGREES) AT TRIANGLE JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C                   COLS 1,2,3 CORRESPOND TO JOINTS 1,2,3. SIZE(3,3).
C  TMAS    = INPUT  EFFECTIVE MASS THICKNESS.
C  RO      = INPUT  MASS DENSITY.
C  NAMEM   = INPUT  TYPE OF MASS MATRIX WANTED.
C                   = M1, LUMPED.
C                   = M2, CONSISTENT.
C  Z       = OUTPUT MASS MATRIX. SIZE(18,18).
   W1      = INPUT  WORK SPACE MATRIX. SIZE(18,18).
C  W2      = INPUT  WORK SPACE MATRIX. SIZE(10,10).
C  KCJ     = INPUT  ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C  KEJ     = INPUT  ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C  KZ      = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=18.
C  KW1     = INPUT  ROW DIMENSION OF W1 IN CALLING PROGRAM. MIN=18.
C  KW2     = INPUT  ROW DIMENSION OF W2 IN CALLING PROGRAM. MIN=10.
C
C     NERROR  EXPLANATION
C  1 = DIMENSION SIZE EXCEEDED (KZ,KW1,KW2).
C  2 = NAMEM IMPROPERLY DEFINED.
C
                                                                NERROR=1
      IF (KZ .LT. 18 .OR. KW1 .LT. 18 .OR. KW2 .LT. 10) GO TO 999
      DO 5 J=1,18
      DO 5 I=1,18
    5 Z(I,J) = 0.0
      SL12 = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
     *                                 + (CJ(3,2)-CJ(3,1))**2)
      SL23 = SQRT((CJ(1,3)-CJ(1,2))**2 + (CJ(2,3)-CJ(2,2))**2
     *                                 + (CJ(3,3)-CJ(3,2))**2)
      SL13 = SQRT((CJ(1,3)-CJ(1,1))**2 + (CJ(2,3)-CJ(2,1))**2
     *                                 + (CJ(3,3)-CJ(3,1))**2)
      X3   = (SL13**2+SL12**2-SL23**2)/(2.0*SL12)
```

```
      Y3    = SQRT(SL13**2-X3**2)
      IF (NAMEM .EQ. 6HM1     ) GO TO 110
      IF (NAMEM .EQ. 6HM2     ) GO TO 120
                                                              NERROR=2
      GO TO 999
C
C  MEMBRANE = M2A1 (LUMPED), BENDING = M2B1 (LUMPED).
  110 CALL M2A1    (SL12,Y3,TMAS,RO,W1,KW1)
      CALL M2B1    (SL12,Y3,TMAS,RO,W1(10,10),KW1)
      DO 115 IW=1,18
      IZ = IVEC(IW)
  115 Z(IZ,IZ) = W1(IW,IW)
      RETURN
C
C  MEMBRANE = M2A2 (CONSISTENT), BENDING = M2B2 (CONSISTENT).
  120 CALL M2A2    (SL12,X3,Y3,TMAS,RO,Z,W1,W2,KZ,KW1,KW2)
      CALL M2B2    (SL12,X3,Y3,TMAS,RO,Z(10,10),W1,W2,KZ,KW1,KW2)
      CALL DCOS2   (CJ,EJ,W1,KCJ,KEJ,KW1)
      CALL BTABA   (Z,W1,18,18,KZ,KW1)
      RETURN
C
  999 CALL ZZBOMB (5HMAS2  ,NERROR)
      END
```

```
      SUBROUTINE MAS3   (CJ,EJ,TMAS,RO,NAMEM,Z,W1,W2,KCJ,KEJ,KZ,KW1,KW2)
      DIMENSION CJ(KCJ,1),EJ(KEJ,1),Z(KZ,1),W1(KW1,1),W2(KW2,1)
      DIMENSION CW(3,3), EW(3,3), IV1(18), IV2(18), IV3(18), IV4(18),
     *          W3(10,10)
      DATA IV1/ 1, 2, 3, 4, 5, 6, 7, 8, 9,10,11,12,13,14,15,16,17,18/,
     *     IV2/ 1, 2, 3, 4, 5, 6,13,14,15,16,17,18,19,20,21,22,23,24/,
     *     IV3/ 1, 2, 3, 4, 5, 6, 7, 8, 9,10,11,12,19,20,21,22,23,24/,
     *     IV4/ 7, 8, 9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24/
C
C   SUBROUTINE TO CALCULATE FINITE ELEMENT...
C      MASS MATRIX
C   FOR A COMBINED MEMBRANE-BENDING QUADRILATERAL PLATE ELEMENT WITH
C   UNRESTRAINED BOUNDARIES.
C   MASS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C   GLOBAL COORDINATE ORDER IS
C      (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2, 3, 4.
C   WHERE U,V,W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS.
C   EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C   CALLS FORMA SUBROUTINES MAS2,REVADD,ZZBOMB.
C   DEVELOPED BY WA BENFIELD, RL WOHLEN. FEBRUARY 1973.
C   LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C      SUBROUTINE ARGUMENTS
C   CJ      = INPUT  MATRIX OF GLOBAL X,Y,Z COORDINATES AT QUAD JOINTS.
C                    ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C                    COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C   EJ      = INPUT  MATRIX OF EULER ANGLES (DEGREES) AT QUAD JOINTS.
C                    ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C                    COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C   TMAS    = INPUT  EFFECTIVE MASS THICKNESS.
C   RO      = INPUT  MASS DENSITY.
C   NAMEM   = INPUT  TYPE OF MASS MATRIX WANTED.
C                    = M1, LUMPED. 4 TRIANGLES, OVERLAP AVERAGE.
C                    = M2, CONSISTENT. 4 TRIANGLES, OVERLAP AVERAGE.
C   Z       = OUTPUT MASS MATRIX. SIZE(24,24).
C   W1      = INPUT  WORK SPACE MATRIX. SIZE(18,18).
C   W2      = INPUT  WORK SPACE MATRIX. SIZE(18,18).
C   KCJ     = INPUT  ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C   KEJ     = INPUT  ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C   KZ      = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=24.
C   KW1     = INPUT  ROW DIMENSION OF W1 IN CALLING PROGRAM. MIN=18.
C   KW2     = INPUT  ROW DIMENSION OF W2 IN CALLING PROGRAM. MIN=18.
C
C      NERROR  EXPLANATION
C   1 = DIMENSION SIZE EXCEEDED (KZ,KW1,KW2).
C   2 = NAMEM IMPROPERLY DEFINED.
C
                                                                 NERROR=1
       IF (KZ .LT. 24 .OR. KW1 .LT. 18 .OR. KW2 .LT. 18) GO TO 999
       DO 5 J=1,24
       DO 5 I=1,24
     5 Z(I,J) = 0.0
       IF (NAMEM .EQ. 6HM1     ) GO TO 110
       IF (NAMEM .EQ. 6HM2     ) GO TO 110
                                                                 NERROR=2
```

```
      GO TO 999
C
  110 DO 112 I=1,3
      CW(I,1) = CJ(I,1)
      EW(I,1) = EJ(I,1)
      CW(I,2) = CJ(I,2)
      EW(I,2) = EJ(I,2)
      CW(I,3) = CJ(I,3)
  112 EW(I,3) = EJ(I,3)
      CALL MAS2    (CW,EW,TMAS,RO,NAMEM,W1,W2,W3,3,3,KW1,KW2,10)
      CALL REVADD (.5,W1,IV1,IV1,Z, 18,18,24,24, KW1,KZ)
      DO 113 I=1,3
      CW(I,1) = CJ(I,1)
      EW(I,1) = EJ(I,1)
      CW(I,2) = CJ(I,3)
      EW(I,2) = EJ(I,3)
      CW(I,3) = CJ(I,4)
  113 EW(I,3) = EJ(I,4)
      CALL MAS2    (CW,EW,TMAS,RO,NAMEM,W1,W2,W3,3,3,KW1,KW2,10)
      CALL REVADD (.5,W1,IV2,IV2,Z, 18,18,24,24, KW1,KZ)
      DO 114 I=1,3
      CW(I,1) = CJ(I,1)
      EW(I,1) = EJ(I,1)
      CW(I,2) = CJ(I,2)
      EW(I,2) = EJ(I,2)
      CW(I,3) = CJ(I,4)
  114 EW(I,3) = EJ(I,4)
      CALL MAS2    (CW,EW,TMAS,RO,NAMEM,W1,W2,W3,3,3,KW1,KW2,10)
      CALL REVADD (.5,W1,IV3,IV3,Z, 18,18,24,24, KW1,KZ)
      DO 115 I=1,3
      CW(I,1) = CJ(I,2)
      EW(I,1) = EJ(I,2)
      CW(I,2) = CJ(I,3)
      EW(I,2) = EJ(I,3)
      CW(I,3) = CJ(I,4)
  115 EW(I,3) = EJ(I,4)
      CALL MAS2    (CW,EW,TMAS,RO,NAMEM,W1,W2,W3,3,3,KW1,KW2,10)
      CALL REVADD (.5,W1,IV4,IV4,Z, 18,18,24,24, KW1,KZ)
      RETURN
C
  999 CALL ZZBOMB (5HMAS3  ,NERROR)
      END
```

```
      SUBROUTINE MAS3A  (CJ,EJ,TMAS,RO,NAMEM,Z,W1,W2,KCJ,KEJ,KZ,KW1,KW2)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(KZ,1), W1(KW1,1), W2(KW2,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     MASS MATRIX
C  FOR A RECTANGULAR SHEAR PANEL ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  MASS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C  GLOBAL COORDINATE ORDER IS
C     (U,V,W) JOINT 1, THEN JOINT 2, 3, 4.
C  WHERE U,V,W ARE TRANSLATIONS.
C  EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C  CALLS FORMA SUBROUTINES M3C1,ZZBOMB.
C  DEVELOPED BY  RL WOHLEN. APRIL 1974.
C  LAST REVISION BY  RL WOHLEN.  MAY 1976.
C
C     SUBROUTINE ARGUMENTS
C  CJ      = INPUT  MATRIX OF GLOBAL X,Y,Z COORDINATES AT PANEL JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C                   COLS 1,2,3,4 CORRESP6ND TO JOINTS 1,2,3,4. SIZE(3,4).
C  EJ      = INPUT  MATRIX OF EULER ANGLES (DEGREES) AT PANEL JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C                   COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C  TMAS    = INPUT  EFFECTIVE MASS THICKNESS.
C  RO      = INPUT  MASS DENSITY.
C  NAMEM   = INPUT  TYPE OF MASS MATRIX WANTED.
C                   = M1, LUMPED.
C  Z       = OUTPUT MASS MATRIX. SIZE(12,12).
C  W1      = INPUT  WORK SPACE MATRIX. SIZE(12,12).
C  W2      = INPUT  WORK SPACE MATRIX. SIZE(**,**).
C  KCJ     = INPUT  ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C  KEJ     = INPUT  ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C  KZ      = INPUT  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=12.
C  KW1     = INPUT  ROW DIMENSION OF W1 IN CALLING PROGRAM. MIN=12.
C  KW2     = INPUT  ROW DIMENSION OF W2 IN CALLING PROGRAM. MIN= *.
C
C     NERROR  EXPLANATION
C  1 = DIMENSION SIZE EXCEEDED (KZ,KW1,KW2).
C  2 = NAMEM IMPROPERLY DEFINED.
C
                                                                NERROR=1
      IF (KZ .LT. 12 .OR. KW1 .LT. 12 .OR. KW2 .LT.  0) GO TO 999
      SL12 = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
     *                                 + (CJ(3,2)-CJ(3,1))**2)
      SL14 = SQRT((CJ(1,4)-CJ(1,1))**2 + (CJ(2,4)-CJ(2,1))**2
     *                                 + (CJ(3,4)-CJ(3,1))**2)
      IF (NAMEM .EQ. 6HM1    ) GO TO 110
                                                                NERROR=2
      GO TO 999
C
C  LUMPED.
  110 DO 112 J=1,12
      DO 112 I=1,12
  112 Z(I,J) = 0.0
      CALL M3C1   (SL12,SL14,TMAS,RO,W1,KW1)
      DO 115 IW=1,4
```

```
      IZ = 3*(IW-1)
      Z(IZ+1,IZ+1) = W1(IW,IW)
      Z(IZ+2,IZ+2) = W1(IW,IW)
  115 Z(IZ+3,IZ+3) = W1(IW,IW)
      RETURN
C
  999 CALL ZZBOMB (6HMAS3A ,NERROR)
      END
```

```
      SUBROUTINE PRESS (CJ,T,NJN,NCOL,KCJ,KW)
      DIMENSION CJ(KCJ,1),T(KW,1)
      DIMENSION A(8,8),JNM(3,42),VN(3),C(3,9),IV(3),JV(9)
C
C
C *** SUBROUTINE TO CALCULATE FLUID ELEMENT PRESSURE TRANSFORMATION
C *** MORE DESCRIPTIVE COMMENT CARDS TO BE ADDED AT A LATER DATE.
C ***             DEVELOPED BY CARL BODLEY, OCTOBER 1974.
C  LAST REVISION BY C S BODLEY.  NOVEMBER 1974.
C
      DATA  JNM  /
     *   1,2,3,  2,4,3,  3,4,1,  1,4,2,  1,2,3,  6,5,4,
     *   2,6,3,  2,5,6,  4,5,2,  4,2,1,  3,6,4,  3,4,1,
     *   3,5,6,  3,2,5,  4,5,1,  1,5,2,  1,3,6,  1,6,4,
     *   1,5,2,  5,6,2,  5,8,7,  5,7,6,  4,7,8,  4,3,7,
     *   1,2,4,  2,3,4,  1,4,5,  4,8,5,  2,6,7,  2,7,3,
     *   1,5,6,  1,6,2,  5,8,6,  6,8,7,  3,7,8,  3,8,4,
     *   1,2,3,  1,3,4,  1,8,5,  1,4,8,  2,6,3,  6,7,3  /
C
      CALL ZERO  (T,NJN,NCOL,KW)
      LO = 18
      NTF = 24
      IF (NJN .EQ. 8) GO TO 5
      LO = 4
      NTF = 14
      IF (NJN .EQ. 6) GO TO 5
      LO = 0
      NTF = 4
    5 CONTINUE
C
      DO 20 N=1,NTF
      LOC = N + LO
      J1 = JNM(1,LOC)
      J2 = JNM(2,LOC)
      J3 = JNM(3,LOC)
      VN(1)=(CJ(2,J2)-CJ(2,J1))*(CJ(3,J3)-CJ(3,J1))
     *    -(CJ(3,J2)-CJ(3,J1))*(CJ(2,J3)-CJ(2,J1))
      VN(2)=(CJ(3,J2)-CJ(3,J1))*(CJ(1,J3)-CJ(1,J1))
     *    -(CJ(1,J2)-CJ(1,J1))*(CJ(3,J3)-CJ(3,J1))
      VN(3)=(CJ(1,J2)-CJ(1,J1))*(CJ(2,J3)-CJ(2,J1))
     *    -(CJ(2,J2)-CJ(2,J1))*(CJ(1,J3)-CJ(1,J1))
      AC = SQRT(VN(1)*VN(1) + VN(2)*VN(2) + VN(3)*VN(3))
      DO 25 I=1,3
   25 VN(I) = VN(I)/AC
      AC = AC/48.
      IF (LOC .LT. 6) AC = 2.*AC
      DO 30 I=1,3
      IV(I) = JNM(I,LOC)
      DO 30 J=1,3
      JI = 3*I - 3 + J
      JL = (IV(I) - 1)*3 + J
   30 JV(JI) = JL
C
      DO 35 L=1,3
      DO 35 I=1,3
```

```
      IL = I + 3*(L - 1)
      DO 35 J=1,3
      F = 1.
      IF (L .EQ. J) F = 2.
   35 C(J,IL) = F*VN(I)
      CALL REVADD (AC,C,IV,JV,T,3,9,NJN,NCOL,3,KW)
   20 CONTINUE
C
      DO 40 I=1,NJN
      DO 40 J=I,NJN
      A(I,J) = 0.
      DO 40 K=1,NCOL
   40 A(I,J) = A(I,J) + T(I,K)*T(J,K)
      CALL INVINP (A,A,NJN,8)
      CALL MULTB (A,T,NJN,NJN,NCOL,8,KW)
C
      RETURN
      END
```

```
      SUBROUTINE QUAD   (XYZ,JDOF,EUL,NUTEL,NJ,
                         NUTMX,NUTKX,NUTBX,NUTLT,NUTST,
                         W,T,S,KX,KJ,KE,KW)
      DIMENSION XYZ(KX,1),JDOF(KJ,1),EUL(KE,1),W(KW,1),T(KW,1),S(KW,1)
      DIMENSION CJ(3,4),EJ(3,4),IVI(24)
      DATA NAMEL/6HQUAD  /,NRW,NRLT/24,24/, IBLNK/6H      /, KCJ/3,
      DATA NIT,NOT/5,6/
C
C  SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
C     MASS MATRICES AND IVECS (ON NUTMX),
C     STIFFNESS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
C     AND IVECS (ON NUTKX),
C     UNIT LOAD BUCKLING MATRICES AND IVECS (ON NUTBX), (NOT YET)
C     LOCAL LOAD TRANSFORMATION MATRICES AND IVECS (ON NUTLT), (NOT YET)
C     STRESS TRANSFORMATION MATRICES AND IVECS (ON NUTST), (NOT YET)
C  FOR COMBINED MEMBRANE-BENDING QUADRILATERAL PLATE ELEMENTS.
C  MASS, STIFFNESS, BUCKLING MATRICES ARE IN GLOBAL COORDINATE
C  DIRECTIONS.
C  GLOBAL COORDINATE ORDER IS
C     (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2, 3, 4.
C  WHERE U,V,W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS.
C  IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
C     IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C     IVEC(3)=0   OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINS
C                 ELEMENT DOF 3 TO ZERO MOTION.
C  GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT QUAD VERTICES IN
C  GLOBAL COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C  DIRECOIONS.
C  ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C     (PU,PV,PW,MP,MQ,MR) JOINT 1, THEN JOINT 2,3,4.
C  WHERE P IS FORCE AND M IS MOMENT.
C  LOCAL LOAD TRANSFORMATION MATRICES RELATES LOAD AT QUAD VERTICES IN
C  LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
C  DIRECTIONS.
C  STRESS TRANSFORMATION MATRICES RELATES STRESS AT QUAD VERTICES IN
C  LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
C  DIRECTIONS.
C  DATA ARRANGEMENT ON NUTMX, NUTKX, NUTBX, NUTLT, NUTST FOR EACH FINITE
C  ELEMENT IS (W=M,K,B,LT,ST)
C     WRITE (NUTWX) NAMEW,NEL,NR,NC,NAMEL,(IBLNK,I=1,5),
C                   ((W(I,J),I=1,NR),J=1,NC),(IVEC(I),I=1,NC)
C  CALLS FORMA SUBROUTINES  MAS3, PAGEHD, STF3, ZZBOMB.
C  DEVELOPED BY WA BENFIELD, CS HODLEY, RL WOHLEN. MARCH 1973.
C  LAST REVISION BY  RL WOHLEN.  MAY 1976.
C
C  ************************************************************************
C  INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = 5, DATA IS
C  READ FROM CARDS.
C     NAMEM,NAMEK,NAMELT,NAMEST,NAMEB                 FORMAT (5(A6,4X)
C     RO,E,ANU                                        FORMAT (3(5X,E10))
C     TMASC,TMEMC,TBENC                               FORMAT (3(5X,E10))
C  20 NEL,J1,J2,J3,J4,TMASV,TMEMV,TBENV               FORMAT (5I5,.E10)
C     IF (J1 .EQ. 0) RETURN
C     GO TO 20
C
```

```
C  DEFINITION OF INPUT VARIABLES.
C  NAMEM  = TYPE OF MASS MATRIX WANTED.
C         = M1, DIAGONAL LUMPED. OVERLAP AVERAGE OF FOUR TRIANGLES.
C         = M2, CONSISTENT. OVERLAP AVERAGE OF FOUR TRIANGLES.
C         = 6H        OR 6HNOMASS, NO MASS MATRIX CALCULATED.
C  NAMEK  = TYPE OF STIFFNESS MATRIX WANTED.
C         = K1, OVERLAP AVERAGE OF FOUR TRIANGLES.
C         = 6H        OR 6HNOSTIF, NO STIFFNESS MATRIX CALCULATED.
C  NAMELT = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES.
C         = 6H        OR 6HNOLOAD, NO LOAD TRANSFORMATIONS CALCULATED.
C  NAMEST = IDENTIFICATION NAME FOR STRESS TRANSFORMATION MATRICES.
C         = 6H        OR 6HNOSTRS, NO STRESS TRANSFORMATIONS CALCULATED.
C  NAMEB  = TYPE OF BUCKLING MATRIX WANTED.
C         = 6H        OR 6HNOBUCK, NO BUCKLING MATRIX CALCULATED.
C  RO     = MASS DENSITY.
C  E      = YOUNGS MODULUS OF ELASTICITY.
C  ANU    = POISSONS RATIO. (E/2G)-1.
C  TMASC  = EFFECTIVE MASS      THICKNESS, (CONSTANT).
C  TMASV  = EFFECTIVE MASS      THICKNESS, (VARIABLE).
C           IF .LE. 0., TMASC IS USED.
C  TMEMC  = EFFECTIVE MEMBRANE THICKNESS, (CONSTANT).
C  TMEMV  = EFFECTIVE MEMBRANE THICKNESS, (VARIABLE).
C           IF .LE. 0., TMEMC IS USED.
C  TBENC  = EFFECTIVE BENDING  THICKNESS, (CONSTANT).
C  TBENV  = EFFECTIVE BENDING  THICKNESS, (VARIABLE).
C           IF .LE. 0., TBENC IS USED.
C  NEL    = FINITE ELEMENT NUMBER. FOR REFERENCE ONLY, NOT USED IN
C           CALCULATIONS. WRITTEN ON NUTMX, ETC.
C  J1     = JOINT NUMBER AT QUADRILATERAL VERTEX 1.
C  J2     = JOINT NUMBER AT QUADRILATERAL VERTEX 2.
C  J3     = JOINT NUMBER AT QUADRILATERAL VERTEX 3.
C  J4     = JOINT NUMBER AT QUADRILATERAL VERTEX 4.
C
C  EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C     I = INTEGER DATA, RIGHT ADJUSTED.
C     E = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED
C     X = CARD COLUMNS SKIPPED.
C  **********************************************************************
C
C     SUBROUTINE ARGUMENTS (ALL INPUT)
C  XYZ    = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND
C           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C           X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
C  JDOF   = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C           TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C           ROTATION DOFS. SIZE(NJ,6).
C  EUL    = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C           GLOBAL X,Y,Z PERMUTATION. SIZE(NJ,3).
C  NUTEL  = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
C           THIS SUBROUTINE. IF NUTEL = 5, DATA IS READ FROM CARDS.
C  NJ     = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C  NUTMX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C           MASS MATRICES AND IVECS ARE OUTPUT.
```

```
C              NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C              USES FORTRAN READ, WRITE.
C   NUTKX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C              STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C              MATRICES) AND IVECS ARE OUTPUT.
C              NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C              USES FORTRAN READ, WRITE.
C   NUTBX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT UNIT LOAD
C              BUCKLING MATRICES AND IVECS ARE OUTPUT.
C              NUTBX MAY BE ZERO IF BUCKLING MATRIX IS NOT FORMED.
C              USES FORTRAN READ, WRITE.
C   NUTLT  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOCAL
C              LOAD TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C              NUTLT MAY BE ZERO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
C              USES FORTRAN READ, WRITE.
C   NUTST  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C              STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C              NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
C              USES FORTRAN READ, WRITE.
C   W      = MATRIX WORK SPACE. MIN SIZE(24,24).
C   T      = MATRIX WORK SPACE. MIN SIZE(24,24).
C   S      = MATRIX WORK SPACE. MIN SIZE(24,24).
C   KX     = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C   KJ     = ROW DIMENSION OF JDOF IN CALLING PROGRAM.
C   KE     = ROW DIMENSION OF EUL IN CALLING PROGRAM.
C   KW     = ROW DIMENSION OF W, T, AND S IN CALLING PROGRAM. MIN=24.
C
C      NERROR  EXPLANATION
C   1 = JOINT NUMBER GREATER THAN NUMBER OF JOINTS.
C   2 = MASS MATRIX FORMED, NUTMX .LE. ZERO.
C   3 = STIFFNESS MATRIX FORMED, NUTKX .LE. ZERO.
C   4 = LT MATRIX FORMED, NUTLT .LE. ZERO.
C   5 = ST MATRIX FORMED, NUTST .LE. ZERO.
C
 1001 FORMAT (5(A6,4X))
 1002 FORMAT (3(5X,E10.0))
 1003 FORMAT (5I5,3E10.0)
 2001 FORMAT (//25X 40HINPUT DATA FOR COMBINED MEMBRANE-BENDING
     *                 29H QUADRILATERAL PLATE ELEMENTS)
 2002 FORMAT (//20X 40HINPUT DATA FOR COMBINED MEMBRANE-BENDING
     *                 41H QUADRILATERAL PLATE ELEMENTS (CONTINUED))
 2003 FORMAT (/ 13X7HMASS = A6, 13X7HSTIF = A6, 6X13HLOAD TRANS = A6,
     *            3X15HSTRESS TRANS = A6, 3X11HBUCKLING = A6,
     *          / 15X4HRO = E10.3, 13X3HE = E10.3,
     *          / 10X9HT(MASS) = E10.3, 12X4HNU = E10.3,
     *          / 32X13HT(MEMBRANE) = E10.3,
     *          / 33X12HT(BENDING) = E10.3,
     *          //12X 7HELEMENT 5X 7HJOINT 1 5X 7HJOINT 2 5X 7HJOINT 3
     *             5X 7HJOINT 4 5X 7HT(MASS) 6X 11HT(MEMBRANE)
     *             5X 10HT(BENDING)
     *           /12X 6HNUMBER 46X 3(5X 10H(VARIABLE) ) )
 2004 FORMAT (12X 5(I5,7X),3(E10.3,5X) )
 2005 FORMAT (12X 5(I5,7X) )
C
C   READ AND WRITE FINITE ELEMENT DATA.
```

```
      NLINE = 0
      CALL PAGEHD
      WRITE (NOT,2001)
      READ (NUTEL,1001) NAMEM,NAMEK,NAMELT,NAMEST,NAMEB
      READ (NUTEL,1002) RO,E,ANU
      READ (NUTEL,1002) TMASC,TMEMC,TBENC
      WRITE (NOT,2003) NAMEM,NAMEK,NAMELT,NAMEST,NAMEB,
     *                 RO,E,TMASC,ANU,TMEMC,TBENC
   20 READ (NUTEL,1003) NEL,J1,J2,J3,J4,TMASV,TMEMV,TBENV
      NO THIK = 1
      IF (TMASV.LE.0. .AND. TMEMV.LE.0. .AND. TBENV.LE.0.) NO THIK=0
      IF (J1 .LE. 0) RETURN
      NLINE = NLINE + 1
      IF (NLINE .LE. 42) GO TO 30
      CALL PAGEHD
      WRITE (NOT,2002)
      WRITE (NOT,2003) NAMEM,NAMEK,NAMELT,NAMEST,NAMEB,
     *                 RO,E,TMASC,ANU,TMEMC,TBENC
      NLINE = 0
   30 IF (NO THIK.EQ.1)
     *WRITE (NOT,2004) NEL,J1,J2,J3,J4,TMASV,TMEMV,TBENV
      IF (NO THIK.EQ.0) WRITE (NOT,2005) NEL,J1,J2,J3,J4
                                                                 NERROR=1
      IF (J1.GT.NJ .OR. J2.GT.NJ .OR. J3.GT.NJ .OR. J4.GT.NJ) GO TO 999
C
C  SET THICKNESSES.
      TMAS = TMASC
      TMEM = TMEMC
      TBEN = TBENC
      IF (TMASV.GT.0.) TMAS=TMASV
      IF (TMEMV.GT.0.) TMEM=TMEMV
      IF (TBENV.GT.0.) TBEN=TBENV
C
C  FORM FINITE ELEMENT COORDINATE LOCATIONS, EULER ANGLES, REVADD IVEC.
      DO 42 I=1,3
      CJ(I,1) = XYZ(J1,I)
      CJ(I,2) = XYZ(J2,I)
      CJ(I,3) = XYZ(J3,I)
      CJ(I,4) = XYZ(J4,I)
      EJ(I,1) = EUL[illegible],I)
      EJ(I,2) = [illegible],I)
      EJ(I,3) = [illegible],I)
   42 EJ(I,4) = [illegible]L(J4,I)
      DO 44 I=1,6
      IV1(I)     = JDOF(J1,I)
      IV1(I+6)   = JDOF(J2,I)
      IV1(I+12)  = JDOF(J3,I)
   44 IV1(I+18)  = JDOF(J4,I)
C
C  FORM MASS MATRIX (W).
      IF [illegible]AMEM .EQ. 6H[illegible] .OR. NAMEM .EQ. 6HNOMASS) GO TO 110
      CA[illegible] MAS[illegible] (CJ,EJ,TMAS,RO,NAMEM,W,[illegible],KCJ,KCJ,KW,KW,KW)
                                                                 NERROR=2
      IF (NUTMX .LE. 0) GO TO 999
      WRITE (NUTMX) NAMEM,NEL,NRW,NR[illegible]NAMEL,(IPLNK,I=1,5),
```

```
                     ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
C
C  FORM STIFFNESS MATRIX (W), LOCAL LOAD TRANSFORMATION MATRIX (T),
C  STRESS TRANSFORMATION MATRIX (S).
  110 IF (NAMEK .EQ. 6H       .OR. NAMEK .EQ. 6HNOSTIF) GO TO 20
      CALL STF3   (CJ,EJ,TMEM,TBEN,E,ANU,NAMEK,NAMEST,W,T,S,NRST,
     *             KCJ,KCJ,KW,KW,KW)
                                                               NERROR=3
      IF (NUTKX .LE. 0) GO TO 999
      WRITE (NUTKX) NAMEK,NEL,NRW,NRW,NAMEL,(IBLNK,I=1,5),
     *               ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
      IF (NAMELT .EQ. 6H        .OR. NAMELT .EQ. 6HNOLOAD) GO TO 115
                                                               NERROR=4
      IF (NUTLT .LE. 0) GO TO 999
      WRITE (NUTLT) NAMELT,NEL,NRLT,NRW,NAMEL,(IBLNK,I=1,5),
     *               ((T(I,J),I=1,NRLT),J=1,NRW),(IV1(I),I=1,NRW)
  115 IF (NAMEST .EQ. 6H        .OR. NAMEST .EQ. 6HNOSTRS) GO TO 20
                                                               NERROR=5
      IF (NUTST .LE. 0) GO TO 999
      WRITE (NUTST) NAMEST,NEL,NRST,NRW,NAMEL,(IBLNK,I=1,5),
     *               ((S(I,J),I=1,NRST),J=1,NRW),(IV1(I),I=1,NRW)
      GO TO 20
C
  999 CALL ZZBOMB (6HQUAD  ,NERROR)
      END
```

```
      SUBROUTINE RECTSP (XYZ,JDOF,EUL,NUTEL,NJ,
     *                   NUTMX,NUTKX,NUTLT,NUTST,
     *                   W,T,S,KX,KJ,KE,KW)
      DIMENSION XYZ(KX,1),JDOF(KJ,1),EUL(KE,1),W(KW,1),T(KW,1),S(KW,1)
      DIMENSION CJ(3,4),FJ(3,4),IV1(12)
      DATA NAMEL/6HRECTSP/, NRW,NRLT/12,8/, IBLNK/6H      /, KCJ/3/
      DATA NIT,NOT/5,6/
C
C  SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
C     MASS MATRICES AND IVECS (ON NUTMX),
C     STIFFNESS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
C     AND IVECS (ON NUTKX),
C     LOCAL LOAD TRANSFORMATION MATRICES AND IVECS (ON NUTLT),
C     STRESS TRANSFORMATION MATRICES AND IVECS (ON NUTST),
C  FOR RECTANGULAR SHEAR PANEL ELEMENTS.
C  MASS, STIFFNESS MATRICES ARE IN GLOBAL COORDINATE DIRECTIONS.
C  GLOBAL COORDINATE ORDER IS
C     (U,V,W) JOINT 1, THEN JOINT 2, 3, 4.
C  WHERE U,V,W ARE TRANSLATIONS.
C  IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
C     IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C     IVEC(3)=0   OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINS
C                 ELEMENT DOF 3 TO ZERO MOTION.
C  GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT PANEL VERTICES IN
C  GLOBAL COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C  DIRECTIONS.
C  ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C     (PU,PV,PW) JOINT 1, THEN JOINT 2, 3, 4.
C  WHERE P IS FORCE.
C  LOCAL LOAD TRANSFORMATION MATRICES RELATES LOAD AT PANEL VERTICES IN
C  LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
C  DIRECTIONS.
C  STRESS TRANSFORMATION MATRICES RELATES PANEL SHEAR STRESS (CONSTANT)
C  IN LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
C  DIRECTIONS.
C  DATA ARRANGEMENT ON NUTMX, NUTKX, NUTLT, NUTST FOR EACH FINITE
C  ELEMENT IS (W=M,K,LT,ST)
C     WRITE (NUTWX) NAMEW,NEL,NR,NC,NAMEL,(IBLNK,I=1,5),
C                  ((W(I,J),I=1,NR),J=1,NC),(IVEC(I),I=1,NC)
C  CALLS FORMA SUBROUTINES MAS3A, PAGEHD, STF3A, ZZBOMB.
C  DEVELOPED BY RL WOHLEN. APRIL 1974.
C  LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C  ***************************************************************************
C  INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = 5, DATA IS
C  READ FROM CARDS.
C     NAMEM,NAMEK,NAMELT,NAMEST                       FORMAT (4(A6,4X)
C     RO,G                                            FORMAT (2(5X,E10))
C     TMAS,TSTF                                       FORMAT (2(5X,E10))
C  20 NEL,J1,J2,J3,J4                                 FORMAT (5I5)
C     IF (J1 .EQ. 0) RETURN
C     GO TO 20
C
C  DEFINITION OF INPUT VARIABLES.
C  NAMEM  = TYPE OF MASS MATRIX WANTED.
```

```
C            = M1, DIAGONAL LUMPED.
C            = M2, CONSISTENT.
C            = 6H          OR 6HNOMASS, NO MASS MATRIX CALCULATED.
C   NAMEK  = TYPE OF STIFFNESS MATRIX WANTED.
C            = K1, LINEAR DISPLACEMENT (CONSTANT STRAIN).
C            = 6H          OR 6HNOSTIF, NO STIFFNESS MATRIX CALCULATED.
C   NAMELT = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES.
C            = 6H          OR 6HNOLOAD, NO LOAD TRANSFORMATIONS CALCULATED.
C   NAMEST = IDENTIFICATION NAME FOR STRESS TRANSFORMATION MATRICES.
C            = 6H          OR 6HNOSTRS, NO STRESS TRANSFORMATIONS CALCULATED.
C   RO     = MASS DENSITY.
C   G      = SHEAR MODULUS OF ELASTICITY.
C   TMAS   = EFFECTIVE MASS      THICKNESS.
C   TSTF   = EFFECTIVE STIFFNESS THICKNESS.
C   NEL    = FINITE ELEMENT NUMBER. FOR REFERENCE ONLY, NOT USED IN
C            CALCULATIONS. WRITTEN ON NUTMX, ETC.
C   J1     = JOINT NUMBER AT PANEL VERTEX 1.
C   J2     = JOINT NUMBER AT PANEL VERTEX 2.
C   J3     = JOINT NUMBER AT PANEL VERTEX 3.
C   J4     = JOINT NUMBER AT PANEL VERTEX 4.
C
C   EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C      I = INTEGER DATA, RIGHT ADJUSTED.
C      E = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.
C      X = CARD COLUMNS SKIPPED.
C   ***********************************************************************
C
C      SUBROUTINE ARGUMENTS (ALL INPUT)
C   XYZ    = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND
C            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C            X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
C   JDOF   = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C            TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C            ROTATION DOFS. SIZE(NJ,6).
C   EUL    = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C            GLOBAL X,Y,Z PERMUTATION. SIZE(NJ,3).
C   NUTEL  = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
C            THIS SUBROUTINE. IF NUTEL = 5, DATA IS READ FROM CARDS.
C   NJ     = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C   NUTMX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C            MASS MATRICES AND IVECS ARE OUTPUT.
C            NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C            USES FORTRAN READ, WRITE.
C   NUTKX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C            STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C            MATRICES) AND IVECS ARE OUTPUT.
C            NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C            USES FORTRAN READ, WRITE.
C   NUTLT  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOCAL
C            LOAD TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C            NUTLT MAY BE ZERO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
C            USES FORTRAN READ, WRITE.
C   NUTST  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
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C            STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C            NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
C            USES FORTRAN READ, WRITE.
C  W       = MATRIX WORK SPACE. MIN SIZE(12,12).
C  T       = MATRIX WORK SPACE. MIN SIZE(12,12).
C  S       = MATRIX WORK SPACE. MIN SIZE(12,12).
C  KX      = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C  KJ      = ROW DIMENSION OF JDOF IN CALLING PROGRAM.
C  KE      = ROW DIMENSION OF EUL IN CALLING PROGRAM.
C  KW      = ROW DIMENSION OF W, T, AND S IN CALLING PROGRAM. MIN=12.
C
C      NERROR  EXPLANATION
C  1 = INPUT JOINT NUMBER EXCEEDS MAXIMUM ALLOWABLE NUMBER OF JOINTS.
C  2 = NUTMX NON POSITIVE.
C  3 = NUTKX NON POSITIVE.
C  4 = NUTLT NON POSITIVE.
C  5 = NUTST NON POSITIVE.
C
 1001 FORMAT (4(A6,4X))
 1002 FORMAT (2(5X,E10.0))
 1003 FORMAT (5I5)
 2001 FORMAT (//38X 47HINPUT DATA FOR RECTANGULAR SHEAR PANEL ELEMENTS)
 2002 FORMAT (//32X 47HINPUT DATA FOR RECTANGULAR SHEAR PANEL ELEMENTS
     *                 12H (CONTINUED))
 2003 FORMAT (/ 14X7HMASS = A6, 14X7HSTIF = A6, 11X13HLOAD TRANS = A6,
     *             8X15HSTRESS TRANS = A6,
     *           / 16X4HRO = E10.3, 14X3HG = E10.3,
     *           / 11X9HT(MASS) = E10.3, 8X9HT(STIF) = E10.3,
     *           //18X7HELEMENT 13X7HJOINT 1 13X7HJOINT 2 13X7HJOINT 3
     *             13X7HJOINT 4 / 18X6HNUMBER)
 2004 FORMAT (18X,5(I5,15X))
C
C  READ AND WRITE FINITE ELEMENT DATA.
      NLINE = 0
      CALL PAGEHD
      WRITE (NOT,2001)
      READ (NUTEL,1001) NAMEM,NAMEK,NAMELT,NAMEST
      READ (NUTEL,1002) RO,G
      READ (NUTEL,1002) TMAS,TSTF
      WRITE (NOT,2003) NAMEM,NAMEK,NAMELT,NAMEST,RO,G,TMAS,TSTF
   20 READ (NUTEL,1003) NEL,J1,J2,J3,J4
      IF (J1 .LE. 0) RETURN
      NLINE = NLINE + 1
      IF (NLINE .LE. 42) GO TO 30
      CALL PAGEHD
      WRITE (NOT,2002)
      WRITE (NOT,2003) NAMEM,NAMEK,NAMELT,NAMEST,RO,G,TMAS,TSTF
      NLINE = 0
   30 WRITE (NOT,2004) NEL,J1,J2,J3,J4
                                                                 NERROR=1
      IF (J1.GT.NJ .OR. J2.GT.NJ .OR. J3.GT.NJ .OR. J4.GT.NJ) GO TO 999
C
C  FORM FINITE ELEMENT COORDINATE LOCATIONS, EULER ANGLES, REVADD IVEC.
      DO 42 I=1,3
      CJ(I,1) = XYZ(J1,I)
```

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      CJ(I,2) = XYZ(J2,I)
      CJ(I,3) = XYZ(J3,I)
      CJ(I,4) = XYZ(J4,I)
      EJ(I,1) = EUL(J1,I)
      EJ(I,2) = EUL(J2,I)
      EJ(I,3) = EUL(J3,I)
   42 EJ(I,4) = EUL(J4,I)
      DO 44 I=1,3
      IV1(I)   = JDOF(J1,I)
      IV1(I+3) = JDOF(J2,I)
      IV1(I+6) = JDOF(J3,I)
   44 IV1(I+9) = JDOF(J4,I)
C
C  FORM MASS MATRIX (W).
      IF (NAMEM .EQ. 6H       .OR. NAMEM .EQ. 6HNOMASS) GO TO 110
      CALL MAS3A  (CJ,EJ,TMAS,RO,NAMEM,W,T,S,KCJ,KCJ,KW,KW,KW)
                                                                 NERROR=2
      IF (NUTMX .LE. 0) GO TO 999
      WRITE (NUTMX) NAMEM,NEL,NRW,NRW,NAMEL,(IBLNK,I=1,5),
     *               ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
C
C  FORM STIFFNESS MATRIX (W), LOCAL LOAD TRANSFORMATION MATRIX (T),
C  STRESS TRANSFORMATION MATRIX (S).
  110 IF (NAMEK .EQ. 6H       .OR. NAMEK .EQ. 6HNOSTIF) GO TO 20
      CALL STF3A  (CJ,EJ,TSTF,G,NAMEK,NAMEST,W,T,S,NRST,
     *              KCJ,KCJ,KW,KW,KW)
                                                                 NERROR=3
      IF (NUTKX .LE. 0) GO TO 999
      WRITE (NUTKX) NAMEK,NEL,NRW,NRW,NAMEL,(IBLNK,I=1,5),
     *               ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
      IF (NAMELT .EQ. 6H       .OR. NAMELT .EQ. 6HNOLOAD) GO TO 115
                                                                 NERROR=4
      IF (NUTLT .LE. 0) GO TO 999
      WRITE (NUTLT) NAMELT,NEL,NRLT,NRW,NAMEL,(IBLNK,I=1,5),
     *               ((T(I,J),I=1,NRLT),J=1,NRW),(IV1(I),I=1,NRW)
  115 IF (NAMEST .EQ. 6H       .OR. NAMEST .EQ. 6HNOSTRS) GO TO 20
                                                                 NERROR=5
      IF (NUTST .LE. 0) GO TO 999
      WRITE (NUTST) NAMEST,NEL,NRST,NRW,NAMEL,(IBLNK,I=1,5),
     *               ((S(I,J),I=1,NRST),J=1,NRW),(IV1(I),I=1,NRW)
      GO TO 20
C
  999 CALL ZZBOMF (6HRECTSP,NERROR)
      END
```

```
      SUBROUTINE STF1A  (CJ,EJ,A1,A2,E,NAMEK,NAMEST,S,TL,TS,NRST,
     *                   KCJ,KEJ,KS,KTL,KTS)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), S(KS,1), TL(KTL,1), TS(KTS,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION MATRIX),
C     LOCAL LOAD TRANSFORMATION MATRIX,
C     STRESS TRANSFORMATION MATRIX,
C  FOR AN AXIAL ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.
C  ROD MAY BE LINEARLY TAPERED OR UNIFORM.
C  STIFFNESS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C  GLOBAL COORDINATE ORDER IS
C     (U,V,W) JOINT 1, THEN JOINT 2.
C  WHERE U,V,W ARE TRANSLATIONS.
C  GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT ROD ENDS IN GLOBAL
C  COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C  DIRECTIONS.
C  ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C     (PU,PV,PW) JOINT 1, THEN JOINT 2.
C  WHERE P IS FORCE.
C  LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT ROD ENDS IN LOCAL
C  COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C  ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
C     PX1,PX2
C  WHERE PX IS AXIAL FORCE.
C  PX1(-), PX2(+) IS TENSION. PX1(+), PX2(-) IS COMPRESSION.
C  STRESS TRANSFORMATION MATRIX RELATES STRESS AT ROD ENDS IN LOCAL
C  COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C  ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C     SIGMA-X1, SIGMA-X2
C  WHERE SIGMA IS NORMAL STRESS.
C  SX1(-), SX2(+) IS TENSION. SX1(+), SX2(-) IS COMPRESSION.
C  EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C  CALLS FORMA SUBROUTINES ATXBA1, DCOS1A, K1A1, MULTA, ZZBOMB.
C  DEVELOPED BY  RL WOHLEN.  SEPTEMBER 1972.
C  LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C     SUBROUTINE ARGUMENTS
C  CJ     = INPUT  MATRIX OF GLOBAL X,Y,Z COORDINATES AT ROD JOINTS.
C                  ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C                  COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C  EJ     = INPUT  MATRIX OF EULER ANGLES (DEGREES) AT ROD JOINTS.
C                  ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C                  COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C  A1     = INPUT  CROSS-SECTION AREA AT ROD END 1.
C  A2     = INPUT  CROSS-SECTION AREA AT ROD END 2.
C  E      = INPUT  YOUNGS MODULUS OF ELASTICITY.
C  NAMEK  = INPUT  TYPE OF STIF MATRIX WANTED.
C                  = K1, CONSTANT AXIAL FORCE ASSUMED.
C  NAMEST = INPUT  OPTION FOR STRESS TRANSFORMATION.
C                  = 6H        OR 6HNOSTRS ,NO STRESS TRANS CALCULATED.
C  S      = OUTPUT STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION
C                  MATRIX). SIZE(6,6).
C  TL     = OUTPUT LOCAL LOAD TRANSFORMATION MATRIX. SIZE(2,6).
C  TS     = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(NRST,6).
```

```
C  NRST    = OUTPUT NUMBER OF ROWS IN STRESS TRANSFORMATION MATRIX.
C  KCJ     = INPUT  ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C  KEJ     = INPUT  ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C  KS      = INPUT  ROW DIMENSION OF S IN CALLING PROGRAM. MIN=6.
C  KTL     = INPUT  ROW DIMENSION OF TL IN CALLING PROGRAM. MIN=2.
C  KTS     = INPUT  ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=NRST.
C
C      NERROR  EXPLANATION
C  1 = SIZE LIMITATION EXCEEDED.
C  2 = NAMEK IMPROPERLY DEFINED.
C
      NRST = 2
                                                             NERROR=1
      IF (KS .LT. 6 .OR. KTL .LT. 2 .OR. KTS .LT. NRST) GO TO 999
      RL = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
     *                              + (CJ(3,2)-CJ(3,1))**2)
      IF (NAMEK .EQ. 6HK1     ) GO TO 110
                                                             NERROR=2
      GO TO 999
  110 CALL K1A1    (A1,A2,RL,E,TL,TS,KTL,KTS)                       TL=K
C
      CALL DCOS1A (CJ,EJ,S,KCJ,KEJ,KS)                              S=DC
      CALL MULTA  (TL,S, 2,2,6, KTL,KS)
      IF (NAMEST .EQ. 6H       .OR. NAMEST .EQ. 6HNOSTRS) GO TO 210
      CALL MULTA  (TS,S,NRST,2,6, KTS,KS)
  210 CALL ATXBA1 (S,TL, 2,6, KS,KTL)
      RETURN
C
  999 CALL ZZBOMB (6HSTF1A  ,NERROR)
      END
```

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      SUBROUTINE STF1B  (CJ,EJ,KODE,A1,A2,TJ1,TJ2,BIZ1,BIZ2,BIY1,BIY2,
     *                   R1,R2,CY1,CY2,CZ1,CZ2,SF,E,G,NAMEK,NAMEST,
     *                   S,TL,TS,NRST,KCJ,KEJ,KS,KTL,KTS)
      DIMENSION CJ(KCJ,1),EJ(KEJ,1),KODE(1),S(KS,1),TL(KTL,1),TS(KTS,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION MATRIX),
C     LOCAL LOAD TRANSFORMATION MATRIX,
C     STRESS TRANSFORMATION MATRIX,
C  FOR A COMBINED AXIAL-TORSION-BENDING BAR ELEMENT WITH UNRESTRAINED
C  BOUNDARIES.
C  BAR MAY BE LINEARLY TAPERED OR UNIFORM.
C  STIFFNESS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C  GLOBAL COORDINATE ORDER IS
C     (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2
C  WHERE U,V,W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS.
C  GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT BAR ENDS IN GLOBAL
C  COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C  DIRECTIONS.
C  ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C     (PU,PV,PW,MP,MQ,MR) JOINT 1, THEN JOINT 2.
C  WHERE P IS FORCE AND M IS MOMENT.
C  LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT BAR ENDS IN LOCAL
C  COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C  ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
C     PX1,PX2,MX1,MX2,PY1,PY2,MZ1,MZ2,PZ1,PZ2,MY1,MY2
C  WHERE P IS FORCE AND M IS MOMENT.
C  STRESS TRANSFORMATION MATRIX RELATES STRESS AT BAR ENDS IN LOCAL
C  COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C  ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C     PX1/A1,PX2/A2,    MX1*R1/TJ1,MX2*R2/TJ2,
C     PY1/A1,PY2/A2,MZ1*CY1/BIZ1,MZ2*CY2/BIZ2,
C     PZ1/A1,PZ2/A2,MY1*CZ1/BIY1,MY2*CZ2/BIY2
C  WHERE P IS FORCE AND M IS MOMENT.
C  EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C  CALLS FORMA SUBROUTINES ATXBA1,DCOS1B,K1A1,K1B1,K1C1,MULTA,ZZBOMB.
C  DEVELOPED BY  RL WOHLEN.  FEBRUARY 1973.
C  LAST REVISION BY  RL WOHLEN.  APRIL 1976.
C
C     SUBROUTINE ARGUMENTS
C  CJ      = INPUT  MATRIX OF GLOBAL X,Y,Z COORDINATES AT BAR JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C                   COLS 1,2 CORRESPOND TO JOINTS 1,2. COL 3 CORRESPONDS
C                   TO REFERENCE POINT TO DEFINE LOCAL XY PLANE. SIZE(3,3).
C  EJ      = INPUT  MATRIX OF EULER ANGLES (DEGREES) AT BAR JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C                   COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C  KODE    = INPUT  OPTION CODE FOR AXIAL, TORSION, BENDING Z, BENDING Y
C                   LOCAL STIFFNESS. IF BLANK, ALL FOUR ARE CALCULATED.
C                   SIZE(4).
C                   KODE(1)=A , LOCAL STIFFNESS MATRIX IS CALCULATED
C                               FOR AXIAL (ALONG LOCAL X-AXIS).
C                   KODE(2)=T , LOCAL STIFFNESS MATRIX IS CALCULATED
C                               FOR TORSION (ABOUT LOCAL X-AXIS).
C                   KODE(3)=BZ, LOCAL STIFFNESS MATRIX IS CALCULATED
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C                             FOR BENDING (ABOUT LOCAL Z-AXIS).
C                     KODE(4)=6Y, LOCAL STIFFNESS MATRIX IS CALCULATED
C                             FOR BENDING (ABOUT LOCAL Y-AXIS).
C  A1     = INPUT  CROSS-SECTION AREA AT BAR END 1.
C  A2     = INPUT  SAME AS A1 AT BAR END 2.
C  TJ1    = INPUT  CROSS-SECTION SAINT VENANTS TORSION CONSTANT (J) IN
C                  JG AT BAR END 1.
C  TJ2    = INPUT  SAME AS TJ1 AT BAR END 2.
C  BIZ1   = INPUT  CROSS-SECTION AREA MOMENT OF INERTIA ABOUT LOCAL
C                  Z-AXIS (FOR BENDING) AT BAR END 1.
C  BIZ2   = INPUT  SAME AS BIZ1 AT BAR END 2.
C  BIY1   = INPUT  CROSS-SECTION AREA MOMENT OF INERTIA ABOUT LOCAL
C                  Y-AXIS (FOR BENDING) AT BAR END 1.
C  BIY2   = INPUT  SAME AS BIY1 AT BAR END 2.
C  R1     = INPUT  DISTANCE FROM LOCAL X-AXIS TO OUTER FIBER FOR
C                  TORSION STRESS CALCULATION AT BAR END 1.
C  R2     = INPUT  SAME AS R1 AT BAR END 2.
C  CY1    = INPUT  DISTANCE FROM XZ PLANE TO OUTER FIBER FOR BENDING
C                  STRESS CALCULATION AT BAR END 1. LOCAL Y DIRECTION.
C  CY2    = INPUT  SAME AS CY1 AT BAR END 2.
C  CZ1    = INPUT  DISTANCE FROM XY PLANE TO OUTER FIBER FOR BENDING
C                  STRESS CALCULATION AT BAR END 1. LOCAL Z DIRECTION.
C  CZ2    = INPUT  SAME AS CZ1 AT BAR END 2.
C  SF     = INPUT  SHAPE FACTOR (K) FOR SHEAR IN KAG.
C                  USE SF=0.0 FOR NO SHEAR DEFORMATION IN BENDING.
C                  SF=1.0 FOR A SOLID CIRCULAR CYLINDER.
C                  SF=.5 FOR A THIN WALLED CIRCULAR CYLINDER.
C  E      = INPUT  YOUNGS MODULUS OF ELASTICITY.
C  G      = INPUT  SHEAR MODULUS OF ELASTICITY.
C  NAMEK  = INPUT  TYPE OF STIF MATRIX WANTED.
C                  = K1, USES K1A1 FOR AXIAL, K1C1 FOR TORSION,
C                        K1B1 FOR BENDING.
C  NAMEST = INPUT  OPTION FOR STRESS TRANSFORMATION.
C                  = 6H        OR 6HNOSTRS ,NO STRESS TRANS CALCULATED.
C  S      = OUTPUT STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION
C                  MATRIX). SIZE(12,12).
C  TL     = OUTPUT LOCAL LOAD TRANSFORMATION MATRIX. SIZE(12,12).
C  TS     = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(NRST,12).
C  NRST   = OUTPUT NUMBER OF ROWS IN STRESS TRANSFORMATION MATRIX.
C  KCJ    = INPUT  ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C  KEJ    = INPUT  ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C  KS     = INPUT  ROW DIMENSION OF S IN CALLING PROGRAM. MIN=12.
C  KTL    = INPUT  ROW DIMENSION OF TL IN CALLING PROGRAM. MIN=12.
C  KTS    = INPUT  ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=NRST.
C
C     NERROR  EXPLANATION
C  1 = SIZE LIMITATION EXCEEDED.
C  2 = NAMEK IMPROPERLY DEFINED.
C
      NRST = 12
                                                             NERROR=1
      IF (KS .LT. 12 .OR. KTL .LT. 12 .OR. KTS .LT. NRST) GO TO 999
      DO 5 J=1,12
      DO 5 I=1,12
      TL(I,J) = 0.0
```

```
    5 TS(I,J) = 0.0
      RL = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
     *                               + (CJ(3,2)-CJ(3,1))**2)
      KODEA = 1
      KODET = 1
      KODEBZ = 1
      KODEBY = 1
      IF (KODE(1).EQ.1H  .AND. KODE(2).EQ.1H  .AND.
     *    KODE(3).EQ.2H  .AND. KODE(4).EQ.2H  ) GO TO 10
      IF (KODE(1) .NE. 1HA ) KODEA = 0
      IF (KODE(2) .NE. 1HT ) KODET = 0
C  LAST HALF OF NEXT TWO CARDS ALLOW FOR OLD DATA. INSERTED APRIL 1976.
      IF (KODE(3) .NE. 2HBZ .AND. KODE(3) .NE. 2HBY) KODEBZ = 0
      IF (KODE(4) .NE. 2HBY .AND. KODE(4) .NE. 2HBZ) KODEBY = 0
   10 IF (NAMEK .EQ. 6HK1     ) GO TO 110
                                                                  NERROR=2
      GO TO 999
C
C  AXIAL = K1A1 (CONSTANT FORCE), TORSION = K1C1 (CONSTANT TORQUE),
C  BENDING = K1B1 (CONSTANT SHEAR, LINEAR BENDING MOMENT).
  110 IF (KODEA  .EQ. 1) CALL K1A1 (A1,A2,RL,E,TL,TS,KTL,KTS)
      IF (KODET  .EQ. 1) CALL K1C1 (TJ1,TJ2,R1,R2,RL,G,TL(3,3),TS(3,3),
     *                              KTL,KTS)
      IF (KODEBZ .EQ. 1) CALL K1B1 (BIZ1,BIZ2,CY1,CY2,A1,A2,SF,RL,E,G,
     *                              TL(5,5),TS(5,5),KTL,KTS)
      DO 115 J=7,8
      DO 115 I=5,6
      TL(I,J) =-TL(I,J)
      TS(I,J) =-TS(I,J)
      TL(J,I) =-TL(J,I)
  115 TS(J,I) =-TS(J,I)
      IF (KODEBY .EQ. 1) CALL K1B1 (BIY1,BIY2,CZ1,CZ2,A1,A2,SF,RL,E,G,
     *                              TL(9,9),TS(9,9),KTL,KTS)             TL=K
C
      CALL DCOS1B (CJ,EJ,S,KCJ,KEJ,KS)                                   S=DC
      CALL MULTA  (TL,S, 12,12,12, KTL,KS)
      IF (NAMEST .EQ. 6H       .OR. NAMEST .EQ. 6HNOSTRS) GO TO 210
      CALL MULTA  (TS,S,NRST,12,12, KTS,KS)
  210 CALL ATXBA1 (S,TL, 12,12, KS,KTL)
      RETURN
C
  999 CALL ZZBOMB (6HSTF1B  ,NERROR)
      END
```

```
      SUBROUTINE STF2  (CJ,EJ,TMEM,T'EN,E,ANU,NAMEK,NAMEST,S,TL,TS,NRST,
     *                  KCJ,KEJ,KS,KTL,KTS)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), S(KS,1), TL(KTL,1), TS(KTS,1)
C
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...
C     STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION MATRIX),
C     LOCAL LOAD TRANSFORMATION MATRIX,
C     STRESS TRANSFORMATION MATRIX,
C  FOR A COMBINED MEMBRANE-BENDING TRIANGLE PLATE ELEMENT WITH
C  UNRESTRAINED BOUNDARIES.
C  STIFFNESS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C  GLOBAL COORDINATE ORDER IS
C     (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2, 3.
C  WHERE U,V,W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS.
C  GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT TRNGL VERTICES IN
C  GLOBAL COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C  DIRECTIONS.
C  ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C     (PU,PV,PW,MP,MQ,MR) JOINT 1, THEN JOINT 2,3.
C  WHERE P IS FORCE AND M IS MOMENT.
C  LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT TRNGL VERTICES IN
C  LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
C  DIRECTIONS.
C  ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
C     (PX,PY,MZ) JOINT 1 THEN 2,3, NEXT
C     (PZ,MX,MY) JOINT 1 THEN 2,3.
C  WHERE P IS FORCE AND M IS MOMENT.
C  STRESS TRANSFORMATION MATRIX RELATES STRESS AT TRNGL VERTICES IN LOCAL
C  COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C  ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C     (SIGMA-X,SIGMA-Y,TAU-XY) FOR (Z=TBEN/2) AT JOINT 1,
C     THEN JOINT 2,3.
C     (SIGMA-X,SIGMA-Y,TAU-XY) FOR (Z=-TBEN/2) AT JOINT 1,
C     THEN JOINT 2,3.
C  WHERE SIGMA IS NORMAL STRESS AND TAU IS SHEAR STRESS.
C  EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C  CALLS FORMA SUBROUTINES ATXBAI,DCOS2,K2A1,K2B1,MULTA,ZZBOMB.
C  DEVELOPED BY  WA BENFIELD.  FEBRUARY 1973.
C  LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C     SUBROUTINE ARGUMENTS
C  CJ     = INPUT  MATRIX OF GLOBAL X,Y,Z COORDINATES AT TRIANGLE JOINTS.
C                  ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C                  COLS 1,2,3 CORRESPOND TO JOINTS 1,2,3. SIZE(3,3).
C  EJ     = INPUT  MATRIX OF EULER ANGLES (DEGREES) AT TRIANGLE JOINTS.
C                  ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C                  COLS 1,2,3 CORRESPOND TO JOINTS 1,2,3. SIZE(3,3).
C  TMEM   = INPUT  EFFECTIVE MEMBRANE THICKNESS.
C  TBEN   = INPUT  EFFECTIVE BENDING  THICKNESS.
C  E      = INPUT  YOUNGS MODULUS OF ELASTICITY.
C  ANU    = INPUT  POISSONS RATIO. (E/2G)-1.
C  NAMEK  = INPUT  TYPE OF STIF MATRIX WANTED.
C                  = K1, USES K2A1 FOR MEMBRANE, K2B1 FOR BENDING.
C  NAMEST = INPUT  OPTION FOR STRESS TRANSFORMATION.
C                  = 6H       OR 6HNOSTRS ,NO STRESS TRANS CALCULATED.
```

```
C  S       = OUTPUT STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION
C                    MATRIX). SIZE(18,18).
C  TL      = OUTPUT LOCAL LOAD TRANSFORMATION MATRIX. SIZE(18,18).
C  TS      = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(NRST,18).
C  NRST    = OUTPUT NUMBER OF ROWS IN STRESS TRANSFORMATION MATRIX.
C  KCJ     = INPUT  ROW DIMENSION OF CJ IN CALLING PROGRAM.
C  KEJ     = INPUT  ROW DIMENSION OF EJ IN CALLING PROGRAM.
C  KS      = INPUT  ROW DIMENSION OF S IN CALLING PROGRAM. MIN=18.
C  KTL     = INPUT  ROW DIMENSION OF TL IN CALLING PROGRAM. MIN=18.
C  KTS     = INPUT  ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=NRST.
C
C     NERROR  EXPLANATION
C  1 = SIZE LIMITATION EXCEEDED.
C  2 = NAMEK IMPROPERLY DEFINED.
C
      NRST = 18
                                                              NERROR=1
      IF (KS .LT. 18 .OR. KTL .LT. 18 .OR. KTS .LT. NRST) GO TO 999
      DO 5 J=1,18
      DO 5 I=1,18
      TL(I,J) = 0.0
    5 TS(I,J) = 0.0
      SL12 = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
     *                                 + (CJ(3,2)-CJ(3,1))**2)
      SL23 = SQRT((CJ(1,3)-CJ(1,2))**2 + (CJ(2,3)-CJ(2,2))**2
     *                                 + (CJ(3,3)-CJ(3,2))**2)
      SL13 = SQRT((CJ(1,3)-CJ(1,1))**2 + (CJ(2,3)-CJ(2,1))**2
     *                                 + (CJ(3,3)-CJ(3,1))**2)
      X3   = (SL13**2+SL12**2-SL23**2)/(2.0*SL12)
      Y3   = SQRT(SL13**2-X3**2)
      IF (NAMEK .EQ. 6HK1     ) GO TO 110
                                                              NERROR=2
      GO TO 999
C
C  MEMBRANE = K2A1 (BODLEY,BENFIELD), BENDING = K2B1 (BODLEY).
  110 CALL K2A1    (SL12,X3,Y3,TMEM,E,ANU,TL,TS,S,KTL,KTS,KS)      TL=K
      CALL K2B1    (SL12,X3,Y3,TBEN,E,ANU,TL(10,10),TS(1,10),S,
     *              KTL,KTS,KS)
      DO 111 I=1,9
      II = I+9
      DO 111 J=1,9
  111 TS(II,J) = TS(I,J)
C
      CALL DCOS2  (CJ,EJ,S,KCJ,KEJ,KS)                             S=DC
      CALL MULTA  (TL,S,18,18,18,KTL,KS)
      IF (NAMEST .EQ. 6H        .OR. NAMEST .EQ. 6HNOSTRS) GO TO 210
      CALL MULTA  (TS,S,NRST,18,18,KTS,KS)
  210 CALL ATXBA1 (S,TL,18,18,KS,KTL)
      RETURN
C
  999 CALL ZZBOMB (5HSTF2  ,NERROR)
      END
```

```
      SUBROUTINE STF3  (CJ,EJ,TMEM,TBEN,E,ANU,NAMEK,NAMEST,S,TL,TS,NRST,
     *                 KCJ,KEJ,KS,KTL,KTS)
      DIMENSION CJ(KCJ,1),EJ(KEJ,1),S(KS,1),TL(KTL,1),TS(KTS,1)
      DIMENSION CW(3,3), EW(3,3), W1(18,18),
     *          IV1(18), IV2(18), IV3(18), IV4(18)
      DATA KCW,KW1 / 3,18 /
      DATA IV1/ 1, 2, 3, 4, 5, 6, 7, 8, 9,10,11,12,13,14,15,16,17,18/,
     *     IV2/ 1, 2, 3, 4, 5, 6,13,14,15,16,17,18,19,20,21,22,23,24/,
     *     IV3/ 1, 2, 3, 4, 5, 6, 7, 8, 9,10,11,12,19,20,21,22,23,24/,
     *     IV4/ 7, 8, 9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24/
C
C   SUBROUTINE TO CALCULATE FINITE ELEMENT...
C      STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION MATRIX),
C      LOCAL LOAD TRANSFORMATION MATRIX (NOT YET),
C      STRESS TRANSFORMATION MATRIX (NOT YET),
C   FOR A COMBINED MEMBRANE-BENDING QUADRILATERAL PLATE ELEMENT WITH
C   UNRESTRAINED BOUNDARIES.
C   STIFFNESS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C   GLOBAL COORDINATE ORDER IS
C      (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2, 3, 4.
C   WHERE U,V,W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS.
C   GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT QUAD VERTICES IN
C   GLOBAL COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C   DIRECTIONS.
C   ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C      (PU,PV,PW,MP,MQ,MR) JOINT 1, THEN JOINT 2,3,4.
C   WHERE P IS FORCE AND M IS MOMENT.
C   LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT QUAD VERTICES
C   IN LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
C   DIRECTION.
C   STRESS TRANSFORMATION MATRIX RELATES STRESS AT QUAD VERTICES IN LOCAL
C   COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTION.
C   EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C   CALLS FORMA SUBROUTINES STF2,REVADD,ZZBOMB.
C   DEVELOPED BY  WA BENFIELD, RL WOHLEN.  FEBRUARY 1973.
C   LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C      SUBROUTINE ARGUMENTS
C   CJ     = INPUT  MATRIX OF GLOBAL X,Y,Z COORDINATES AT QUAD JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C                   COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C   EJ     = INPUT  MATRIX OF EULER ANGLES (DEGREES) AT QUAD JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C                   COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C   TMEM   = INPUT  EFFECTIVE MEMBRANE THICKNESS.
C   TBEN   = INPUT  EFFECTIVE BENDING  THICKNESS.
C   E      = INPUT  YOUNGS MODULUS OF ELASTICITY.
C   ANU    = INPUT  POISSONS RATIO. (E/2G)-1.
C   NAMEK  = INPUT  TYPE OF STIF MATRIX WANTED.
C                   = K1, USES 4 TRIANGLES, OVERLAP AVERAGE.
C   NAMEST = INPUT  OPTION FOR STRESS TRANSFORMATION.
C                   = 6H        OR 6HNOSTRS ,NO STRESS TRANS CALCULATED.
C   S      = OUTPUT STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION
C                   MATRIX). SIZE(24,24).
C   TL     = OUTPUT LOCAL LOAD TRANSFORMATION MATRIX. SIZE(24,24).
```

```
C  TS      = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(NRST,24).
C  NRST    = OUTPUT NUMBER OF ROWS IN STRESS TRANSFORMATION MATRIX.
C  KCJ     = INPUT  ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C  KEJ     = INPUT  ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C  KS      = INPUT  ROW DIMENSION OF S IN CALLING PROGRAM. MIN=24.
C  KTL     = INPUT  ROW DIMENSION OF TL IN CALLING PROGRAM. MIN=24.
C  KTS     = INPUT  ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=NRST.
C
C     NERROR  EXPLANATION
C  1 = SIZE LIMITATION EXCEEDED.
C  2 = NAMEK IMPROPERLY DEFINED.
C
      NRST = 24
                                                                NERROR=1
      IF (KS .LT. 24 .OR. KTL .LT. 24 .OR. KTS .LT. NRST) GO TO 999
      DO 5 J=1,24
      DO 5 I=1,24
    5 S(I,J) = 0.0
      IF (NAMEK .EQ. 6HKI     ) GO TO 110
                                                                NERROR=2
      GO TO 999
C
  110 DO 200 I=1,3
      CW(I,1) = CJ(I,1)
      EW(I,1) = EJ(I,1)
      CW(I,2) = CJ(I,2)
      EW(I,2) = EJ(I,2)
      CW(I,3) = CJ(I,3)
  200 EW(I,3) = EJ(I,3)
      CALL STF2    (CW,EW,TMEM,TBEN,E,ANU,NAMEK,NAMEST,W1,TL,TS,NRSTX,
     *              KCW,KCW,KW1,KTL,KTS)
      CALL REVADD (.5,W1,IV1,IV1,S, 18,18,24,24, 18,KS)
      DO 201 I=1,3
      CW(I,1) = CJ(I,1)
      EW(I,1) = EJ(I,1)
      CW(I,2) = CJ(I,3)
      EW(I,2) = EJ(I,3)
      CW(I,3) = CJ(I,4)
  201 EW(I,3) = EJ(I,4)
      CALL STF2    (CW,EW,TMEM,TBEN,E,ANU,NAMEK,NAMEST,W1,TL,TS,NRSTX,
     *              KCW,KCW,KW1,KTL,KTS)
      CALL REVADD (.5,W1,IV2,IV2,S, 18,18,24,24, 18,KS)
      DO 203 I=1,3
      CW(I,1) = CJ(I,1)
      EW(I,1) = EJ(I,1)
      CW(I,2) = CJ(I,2)
      EW(I,2) = EJ(I,2)
      CW(I,3) = CJ(I,4)
  203 EW(I,3) = EJ(I,4)
      CALL STF2    (CW,EW,TMEM,TBEN,E,ANU,NAMEK,NAMEST,W1,TL,TS,NRSTX,
     *              KCW,KCW,KW1,KTL,KTS)
      CALL REVADD (.5,W1,IV3,IV3,S, 18,18,24,24, 18,KS)
      DO 205 I=1,3
      CW(I,1) = CJ(I,2)
      EW(I,1) = EJ(I,2)
```

```
      CW(I,2) = CJ(I,3)
      EW(I,2) = EJ(I,3)
      CW(I,3) = CJ(I,4)
  205 EW(I,3) = EJ(I,4)
      CALL STF2    (CW,EW,TMEM,TBEN,E,ANU,NAMEK,NAMEST,W1,TL,TS,NRSTX,
     *              KCW,KCW,KW1,KTL,KTS)
      CALL REVADD (.5,W1,IV4,IV4,S, 18,18,24,24, 18,KS)
C
      DO 300 J=1,24
      DO 300 I=1,24
      TL(I,J) = 0.0
  300 TS(I,J) = 0.0
      RETURN
C
  999 CALL ZZBOMB (4HSTF3   ,NERROR)
      END
```

```
      SUBROUTINE STF3A (CJ,EJ,TH,G,NAMEK,NAMEST,S,TL,TS,NRST,
     *                  KCJ,KEJ,KS,KTL,KTS)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), S(KS,1), TL(KTL,1), TS(KTS,1)
C
C   SUBROUTINE TO CALCULATE FINITE ELEMENT...
C      STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION MATRIX),
C      LOCAL LOAD TRANSFORMATION MATRIX,
C      STRESS TRANSFORMATION MATRIX,
C   FOR A RECTANGULAR SHEAR PANEL ELEMENT WITH UNRESTRAINED BOUNDARIES.
C   STIFFNESS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C   GLOBAL COORDINATE ORDER IS
C      (U,V,W) JOINT 1, THEN JOINT 2, 3, 4.
C   WHERE U,V,W ARE TRANSLATIONS.
C   GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT PANEL VERTICES IN
C   GLOBAL COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C   DIRECTIONS.
C   ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C      (PU,PV,PW) JOINT 1, THEN JOINT 2, 3, 4.
C   WHERE P IS FORCE.
C   LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT PANEL VERTICES IN
C   LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
C   DIRECTIONS.
C   ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
C      PX1,PX2,PX3,PX4, PY1,PY2,PY3,PY4
C   WHERE P IS FORCE. X GOES FROM 1 TO 2. Y GOES FROM 1 TO 4.
C   STRESS TRANSFORMATION MATRIX RELATES PANEL SHEAR STRESS (CONSTANT) IN
C   LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORD DIRECTIONS.
C   EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C   CALLS FORMA SUBROUTINES ATXBA1,DCOS3C,K3C1,MULTA,ZZBOMB.
C   DEVELOPED BY  RL WOHLEN. APRIL 1974.
C   LAST REVISION BY WA BENFIELD.  MARCH 1976.
C
C      SUBROUTINE ARGUMENTS
C   CJ     = INPUT  MATRIX OF GLOBAL X,Y,Z COORDINATES AT PANEL JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C                   COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C   EJ     = INPUT  MATRIX OF EULER ANGLES (DEGREES) AT PANEL JOINTS.
C                   ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C                   COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C   TH     = INPUT  PANEL THICKNESS.
C   G      = INPUT  SHEAR MODULUS OF ELASTICITY.
C   NAMEK  = INPUT  TYPE OF STIF MATRIX WANTED.
C                   = K1, USES K3C1.
C   NAMEST = INPUT  OPTION FOR STRESS TRANSFORMATION.
C                   = 6H       OR 6HNOSTRS ,NO STRESS TRANS CALCULATED.
C   S      = OUTPUT STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION
C                   MATRIX). SIZE(12,12).
C   TL     = OUTPUT LOCAL LOAD TRANSFORMATION MATRIX. SIZE(8,12).
C   TS     = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(1,12).
C   NRST   = OUTPUT NUMBER OF ROWS (1) IN STRESS TRANSFORMATION MATRIX.
C   KCJ    = INPUT  ROW DIMENSION OF CJ IN CALLING PROGRAM.
C   KEJ    = INPUT  ROW DIMENSION OF EJ IN CALLING PROGRAM.
C   KS     = INPUT  ROW DIMENSION OF S IN CALLING PROGRAM. MIN=12.
C   KTL    = INPUT  ROW DIMENSION OF TL IN CALLING PROGRAM. MIN=8.
C   KTS    = INPUT  ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=1.
```

```
C
C      NERROR  EXPLANATION
C   1 = SIZE LIMITATION EXCEEDED.
C   2 = NAMEK IMPROPERLY DEFINED.
C
      NRST = 1
                                                                NERROR=1
      IF (KS .LT. 12 .OR. KTL .LT. 8 .OR. KTS .LT. NRST) GO TO 999
      SL12 = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
     *                                 + (CJ(3,2)-CJ(3,1))**2)
      SL14 = SQRT((CJ(1,4)-CJ(1,1))**2 + (CJ(2,4)-CJ(2,1))**2
     *                                 + (CJ(3,4)-CJ(3,1))**2)
      IF (NAMEK .EQ. 6HK1    ) GO TO 110
                                                                NERROR=2
      GO TO 999
C
  110 CALL K3C1   (SL12,SL14,TH,G,TL,TS,KTL,KTS)                       TL=K
C
      CALL DCOS3C (CJ,EJ,S,KCJ,KEJ,KS)                                 S=DC
      CALL MULTA  (TL,S,8,8,12,KTL,KS)
      IF (NAMEST .EQ. 6H      .OR. NAMEST .EQ. 6HNOSTRS) GO TO 210
      CALL MULTA  (TS,S,NRST,8,12,KTS,KS)
  210 CALL ATXBA1 (S,TL,8,12,KS,KTL)
      RETURN
C
  999 CALL ZZBOMB (6HSTF3A ,NERROR)
      END
```

```
      SUBROUTINE TEGEOM (CJ,JM,      VL,DV,       KCJ,    IFBAD)
      DIMENSION CJ(KCJ,1), JM(     1),          DV(1)
      DIMENSION       R12(3),R13(3),R14(3)
      DATA EPS / 1.E-5 /
C
C  SUBROUTINE TO DETERMINE THE VOLUME AND VOLUME CHANGE COEFFICIENTS OF
C  A TETRAHEDRON.
C  CALLS FORMA SUBROUTINES VCROSS,VDOT  .
C  DEVELOPED BY C S BODLEY.  FEBRUARY 1974.
C  LAST REVISION BY R A PHILIPPUS.  AUGUST 1974.
C     SUBROUTINE ARGUMENTS
C  CJ    = INPUT  MATRIX OF JOINT COORDINATES. SIZE(3,8).
C  JM    = INPUT  VECTOR OF JOINTS DEFINING A TETRAHEDRON. SIZE (4).
C  VL    = OUTPUT VOLUME OF TETRAHEDRON DEFINED BY JM.
C  DV    = OUTPUT VECTOR OF VOLUME CHANGE COEFFICIENTS.
C  KCJ   = INPUT  ROW DIMENSION SIZE OF CJ IN CALLING PROGRAM. MIN = 3.
C  IFBAD = OUTPUT
C          = 0 . THE TETRAHEDRON VERTICIES ARE NOT NUMBERED ACCORDING
C                TO THE ESTABLISHED CONVENTION, OR LIE IN A PLANE.
C
      J1 = JM(1    )
      J2 = JM(2    )
      J3 = JM(3    )
      J4 = JM(4    )
      DO 5 I=1,3
      R12(I) = CJ(I,J2) - CJ(I,J1)
      R13(I) = CJ(I,J3) - CJ(I,J1)
    5 R14(I) = CJ(I,J4) - CJ(I,J1)
C
      CALL VCROSS (R12,R13,DV(10),VAMAG,VBMAG,VZMAG,SINAB)
      CALL VDOT   (DV(10),R14,VOL,VAMAG,VBMAG,COSAB)
      IF (VOL.LE.EPS) IFBAD=0
      VL     = VOL/6.
C
      CALL VCROSS (R13,R14,DV(4), VAMAG,VBMAG,VZMAG,SINAB)
      CALL VCROSS (R14,R12,DV(7), VAMAG,VBMAG,VZMAG,SINAB)
      DO 10 I=1,3
   10 DV(I) = -DV(I+3) - DV(I+6) - DV(I+9)
      DO 15 I=1,12
   15 DV(I) = DV(I)/6.
C
      RETURN
      END
```

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      SUBROUTINE TRNGL  (XYZ,JDOF,EUL,NUTEL,NJ,
     *                   NUTMX,NUTKX,NUTBX,NUTLT,NUTST,
     *                   W,T,S,KX,KJ,KE,KW)
      DIMENSION XYZ(KX,1),JDOF(KJ,1),EUL(KE,1),W(KW,1),T(KW,1),S(KW,1)
      DIMENSION CJ(3,3), EJ(3,3), IV1(18)
      DATA NAME /6HTRNGL /, NRW,NRLT/18,18/, IBLNK/6H      /, KCJ/3/
      DATA NIT,NCT/5,6/
C
C  SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
C     MASS MATRICES AND IVECS (ON NUTMX),
C     STIFFNESS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
C     AND IVECS (ON NUTKX),
C     UNIT LOAD BUCKLING MATRICES AND IVECS (ON NUTBX), (NOT YET)
C     LOCAL LOAD TRANSFORMATION MATRICES AND IVECS (ON NUTLT),
C     STRESS TRANSFORMATION MATRICES AND IVECS (ON NUTST),
C  FOR COMBINED MEMBRANE-BENDING TRIANGLE PLATE ELEMENTS.
C  MASS, STIFFNESS, BUCKLING MATRICES ARE IN GLOBAL COORDINATE
C  DIRECTIONS.
C  GLOBAL COORDINATE ORDER IS
C     (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2, 3.
C  WHERE U,V,W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS.
C  IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
C     IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C     IVEC(3)=0   OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINS
C                 ELEMENT DOF 3 TO ZERO MOTION.
C  GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT TRNGL VERTICES IN
C  GLOBAL COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C  DIRECTIONS.
C  ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C     (PU,PV,PW,MP,MQ,MR) JOINT 1, THEN JOINT 2,3.
C  WHERE P IS FORCE AND M IS MOMENT.
C  LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT TRNGL VERTICES IN
C  LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
C  DIRECTIONS.
C  ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
C     (PX,PY,MZ) JOINT 1 THEN 2,3, NEXT
C     (PZ,MX,MY) JOINT 1 THEN 2,3.
C  WHERE P IS FORCE AND M IS MOMENT.
C  STRESS TRANSFORMATION MATRIX RELATES STRESS AT TRNGL VERTICES IN LOCAL
C  COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C  ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C     (SIGMA-X,SIGMA-Y,TAU-XY) FOR (Z=TBEN/2) AT JOINT 1,
C     THEN JOINT 2,3.
C     (SIGMA-X,SIGMA-Y,TAU-XY) FOR (Z=-TBEN/2) AT JOINT 1,
C     THEN JOINT 2,3.
C  WHERE SIGMA IS NORMAL STRESS AND TAU IS SHEAR STRESS.
C  DATA ARRANGEMENT ON NUTMX, NUTKX, NUTBX, NUTLT, NUTST FOR EACH
C  FINITE ELEMENT IS (W=M,K,B,LT,ST)
C     WRITE (NUTWX) NAMEW,NEL,NR,NC,NAMEL,(IBLNK,I=1,5),
C                   ((W(I,J),I=1,NR),J=1,NC),(IVEC(I),I=1,NC)
C  CALLS FORMA SUBROUTINES  MAS2, PAGEHD, STF2, ZZBOMB.
C  DEVELOPED BY WA BENFIELD, CS BODLEY, RL WOHLEN. FEBRUARY 1973.
C  LAST REVISION BY  RL WOHLEN.  MAY 1976.
C
C  ****************************************************************************
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C  INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = 5, DATA IS
C  READ FROM CARDS.
C     NAMEM,NAMEK,NAMELT,NAMEST,NAMEB                   FORMAT (5(A6,4X)
C     RO,E,ANU                                          FORMAT (3(5X,E10))
C     TMASC,TMEMC,TBENC                                 FORMAT (3(5X,E10))
C  20 NEL,J1,J2,J3,TMASV,TMEMV,TBENV                    FORMAT (4I5,3E10)
C     IF (J1 .EQ. 0) RETURN
C     GO TO 20
C
C  DEFINITION OF INPUT VARIABLES.
C  NAMEM  = TYPE OF MASS MATRIX WANTED.
C         = M1, DIAGONAL LUMPED.
C         = M2, CONSISTENT.
C         = 6H        OR 6HNOMASS, NO MASS MATRIX CALCULATED.
C  NAMEK  = TYPE OF STIFFNESS MATRIX WANTED.
C         = K1, QUADRATIC DISPLACEMENT FOR MEMBRANE, CUBIC
C               DISPLACEMENT FOR BENDING.
C         = 6H        OR 6HNOSTIF, NO STIFFNESS MATRIX CALCULATED.
C  NAMELT = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES.
C         = 6H        OR 6HNOLOAD, NO LOAD TRANSFORMATIONS CALCULATED.
C  NAMEST = IDENTIFICATION NAME FOR STRESS TRANSFORMATION MATRICES.
C         = 6H        OR 6HNOSTRS, NO STRESS TRANSFORMATIONS CALCULATED.
C  NAMEB  = TYPE OF BUCKLING MATRIX WANTED.
C         = 6H        OR 6HNOBUCK, NO BUCKLING MATRIX CALCULATED.
C  RO     = MASS DENSITY.
C  E      = YOUNGS MODULUS OF ELASTICITY.
C  ANU    = POISSONS RATIO. (E/2G)-1.
C  TMASC  = EFFECTIVE MASS     THICKNESS, (CONSTANT).
C  TMASV  = EFFECTIVE MASS     THICKNESS, (VARIABLE).
C           IF .LE. 0., TMASC IS USED.
C  TMEMC  = EFFECTIVE MEMBRANE THICKNESS, (CONSTANT).
C  TMEMV  = EFFECTIVE MEMBRANE THICKNESS, (VARIABLE).
C           IF .LE. 0., TMEMC IS USED.
C  TBENC  = EFFECTIVE BENDING  THICKNESS, (CONSTANT).
C  TBENV  = EFFECTIVE BENDING  THICKNESS, (VARIABLE).
C           IF .LE. 0., TBENC IS USED.
C  NEL    = FINITE ELEMENT NUMBER. FOR REFERENCE ONLY, NOT USED IN
C           CALCULATIONS. WRITTEN ON NUTMX, ETC.
C  J1     = JOINT NUMBER AT TRIANGLE VERTEX 1.
C  J2     = JOINT NUMBER AT TRIANGLE VERTEX 2.
C  J3     = JOINT NUMBER AT TRIANGLE VERTEX 3.
C
C  EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C     I = INTEGER DATA, RIGHT ADJUSTED.
C     E = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.
C     X = CARD COLUMNS SKIPPED.
C  ***********************************************************************
C
C     SUBROUTINE ARGUMENTS (ALL INPUT)
C  XYZ    = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND
C           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C           X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
C  JDOF   = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C           TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
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C            ROTATION DOFS. SIZE(NJ,6).
C   EUL    = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C            GLOBAL X,Y,Z PERMUTATION. SIZE(NJ,3).
C   NUTEL  = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
C            THIS SUBROUTINE. IF NUTEL = 5, DATA IS READ FROM CARDS.
C   NJ     = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C   NUTMX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C            MASS MATRICES AND IVECS ARE OUTPUT.
C            NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C            USES FORTRAN READ, WRITE.
C   NUTKX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C            STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C            MATRICES) AND IVECS ARE OUTPUT.
C            NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C            USES FORTRAN READ, WRITE.
C   NUTBX  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT UNIT LOAD
C            BUCKLING MATRICES AND IVECS ARE OUTPUT.
C            NUTBX MAY BE ZERO IF BUCKLING MATRIX IS NOT FORMED.
C            USES FORTRAN READ, WRITE.
C   NUTLT  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOCAL
C            LOAD TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C            NUTLT MAY BE ZERO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
C            USES FORTRAN READ, WRITE.
C   NUTST  = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C            STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C            NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
C            USES FORTRAN READ, WRITE.
C   W      = MATRIX WORK SPACE. MIN SIZE(18,18).
C   T      = MATRIX WORK SPACE. MIN SIZE(18,18).
C   S      = MATRIX WORK SPACE. MIN SIZE(18,18).
C   KX     = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C   KJ     = ROW DIMENSION OF JDOF IN CALLING PROGRAM.
C   KE     = ROW DIMENSION OF EUL IN CALLING PROGRAM.
C   KW     = ROW DIMENSION OF W, T, AND S IN CALLING PROGRAM. MIN=18.
C
C      NERROR  EXPLANATION
C   1 = JOINT NUMBER GREATER THAN NUMBER OF JOINTS.
C   2 = MASS MATRIX FORMED, NUTMX .LE. ZERO.
C   3 = STIFFNESS MATRIX FORMED, NUTKX .LE. ZERO.
C   4 = LT MATRIX FORMED, NUTLT .LE. ZERO.
C   5 = ST MATRIX FORMED, NUTST .LE. ZERO.
C
 1001 FORMAT (5(A6,4X))
 1002 FORMAT (3(5X,E10.0))
 1003 FORMAT (4I5,3E10.0)
 2001 FORMAT (//32X 49HINPUT DATA FOR COMBINED MEMBRANE-BENDING TRIANGLE
     *                15H PLATE ELEMENTS)
 2002 FORMAT (//26X 49HINPUT DATA FOR COMBINED MEMBRANE-BENDING TRIANGLE
     *                27H PLATE ELEMENTS (CONTINUED))
 2003 FORMAT (/ 13X7HMASS = A6, 13X7HSTIF = A6, 6X13HLOAD TRANS = A6,
     *             3X15HSTRESS TRANS = A6, 3X11HBUCKLING = A6,
     *          / 15X4HRO = E10.3, 13X3HE = E10.3,
     *          / 10X9HT(MASS) = E10.3, 12X4HNU = E10.3,
     *          / 32X13HT(MEMBRANE) = E10.3,
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     *          / 33X12HT(BENDING) = E10.3,
     *          //18X 7HELEMENT 5X 7HJOINT 1 5X 7HJOINT 2 5X 7HJOINT 3
     *             5X 7HT(MASS) 6X 11HT(MEMBRANE) 5X 10HT(BENDING)
     *           /18X 6HNUMBER 36X 3(5X 10H(VARIABLE) ) )
 2004 FORMAT (18X 4(I5,7X),3(E10.3,5X) )
 2005 FORMAT (18X 4(I5,7X) )
C
C  READ AND WRITE FINITE ELEMENT DATA.
      NLINE = 0
      CALL PAGEHD
      WRITE (NOT,2001)
      READ (NUTEL,1001) NAMEM,NAMEK,NAMELT,NAMEST,NAMEB
      READ (NUTEL,1002) RO,E,ANU
      READ (NUTEL,1002) TMASC,TMEMC,TBENC
      WRITE (NOT,2003) NAMEM,NAMEK,NAMELT,NAMEST,NAMEB,
     *                 RO,E,TMASC,ANU,TMEMC,TBENC
   20 READ (NUTEL,1003) NEL,J1,J2,J3,TMASV,TMEMV,TBENV
      NO THIK = 1
      IF (TMASV.LE.0. .AND. TMEMV.LE.0. .AND. TBENV.LE.0.) NO THIK=0
      IF (J1 .LE. 0) RETURN
      NLINE = NLINE + 1
      IF (NLINE .LE. 42) GO TO 30
      CALL PAGEHD
      WRITE (NOT,2002)
      WRITE (NOT,2003) NAMEM,NAMEK,NAMELT,NAMEST,NAMEB,
     *                 RO,E,TMASC,ANU,TMEMC,TBENC
      NLINE = 0
   30 IF (NO THIK.EQ.1)
     *WRITE (NOT,2004) NEL,J1,J2,J3,TMASV,TMEMV,TBENV
      IF (NO THIK.EQ.0) WRITE (NOT,2005) NEL,J1,J2,J3
                                                            NERROR=1
      IF (J1 .GT. NJ .OR. J2 .GT. NJ .OR. J3 .GT. NJ) GO TO 999
C
C  SET THICKNESSES.
      TMAS = TMASC
      TMEM = TMEMC
      TBEN = TBENC
      IF (TMASV.GT.0.) TMAS=TMASV
      IF (TMEMV.GT.0.) TMEM=TMEMV
      IF (TBENV.GT.0.) TBEN=TBENV
C
C  FORM FINITE ELEMENT COORDINATE LOCATIONS, EULER ANGLES, REVADD IVEC.
      DO 42 I=1,3
      CJ(I,1) = XYZ(J1,I)
      CJ(I,2) = XYZ(J2,I)
      CJ(I,3) = XYZ(J3,I)
      EJ(I,1) = EUL(J1,I)
      EJ(I,2) = EUL(J2,I)
   42 EJ(I,3) = EUL(J3,I)
      DO 44 I=1,6
      IV1(I)    = JDOF(J1,I)
      IV1(I+6)  = JDOF(J2,I)
   44 IV1(I+12) = JDOF(J3,I)
C
C  FORM MASS MATRIX (W).
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      IF (NAMEM .EQ. 6H       .OR. NAMEM .EQ. 6HNOMASS) GO TO 110
      CALL MAS2    (CJ,EJ,TMAS,RO,NAMEM,W,T,S,KCJ,KCJ,KW,KW,KW)
                                                            NERROR=2
      IF (NUTMX .LE. 0) GO TO 999
      WRITE (NUTMX) NAMEM,NEL,NRW,NRW,NAMEL,(IBLNK,I=1,5),
     *              ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
C
C  FORM STIFFNESS MATRIX (W), LOCAL LOAD TRANSFORMATION MATRIX (T),
C  STRESS TRANSFORMATION MATRIX (S).
  110 IF (NAMEK .EQ. 6H       .OR. NAMEK .EQ. 6HNOSTIF) GO TO 20
      CALL STF2    (CJ,EJ,TMEM,TBEN,E,ANU,NAMEK,NAMEST,W,T,S,NRST,
     *             KCJ,KCJ,KW,KW,KW)
                                                            NERROR=3
      IF (NUTKX .LE. 0) GO TO 999
      WRITE (NUTKX) NAMEK,NEL,NRW,NRW,NAMEL,(IBLNK,I=1,5),
     *              ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
      IF (NAMELT .EQ. 6H       .OR. NAMELT .EQ. 6HNOLOAD) GO TO 115
                                                            NERROR=4
      IF (NUTLT .LE. 0) GO TO 999
      WRITE (NUTLT) NAMELT,NEL,NRLT,NRW,NAMEL,(IBLNK,I=1,5),
     *              ((T(I,J),I=1,NRLT),J=1,NRW),(IV1(I),I=1,NRW)
  115 IF (NAMEST .EQ. 6H       .OR. NAMEST .EQ. 6HNOSTRS) GO TO 20
                                                            NERROR=5
      IF (NUTST .LE. 0) GO TO 999
      WRITE (NUTST) NAMEST,NEL,NRST,NRW,NAMEL,(IBLNK,I=1,5),
     *              ((S(I,J),I=1,NRST),J=1,NRW),(IV1(I),I=1,NRW)
      GO TO 20
C
  999 CALL ZZBOMB (6HTRNGL ,NERROR)
      END
```